

9950-514

RE-ENTRY SYSTEMS DIVISION

PHILADELPHIA, PENNSYLVANIA

GENERIC AEROCAPTURE

ATMOSPHERIC ENTRY STUDY

FINAL REPORT

VOLUME II: TRAJECTORY APPENDICES

CONTRACT NO. 955689



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ATMOSPHERIC ENTRY STUDY. VOLUME 2:
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GENERIC AEROCAPTURE
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RE-ENTRY SYSTEMS DIVISION
3198 Chestnut St. Philadelphia, PA 19101

GENERAL  ELECTRIC

INTRODUCTION

Aerocapture trajectories were run for several combinations of entry path angles and velocities for the S02P, MSR and Uranus missions. The S02P trajectories represent a Titan atmospheric entry for orbit about Saturn; the MSR trajectories represent a Mars atmospheric entry for orbit about Mars; similarly, the Uranus trajectories enter an Uranus atmosphere to achieve orbit about Uranus. Aerothermodynamic and control system parameters and performance are discussed in Volume I of this final report.

Each trajectory set contains the following parametric relationships:

QB vs VA	Dynamic Pressure (N/m^2) vs Air Relative Velocity (m/sec)
H vs DRNG	Altitude (m) vs Downrange Distance (km)
H vs T	Altitude (m) vs Time (sec)
VA vs T	Air Relative Velocity (m/sec) vs Time (sec)
FPA vs T	Air Relative Flight Path Angle (degrees) vs Time (sec)
RGCD vs T	Bank Angle Command (deg) vs Time (sec)

The Mars and Uranus trajectories also include:

AXW vs T	Drag (m/sec^2) vs Time (sec)
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B	MSR TRAJECTORIES
C	URANUS TRAJECTORIES

APPENDIX A

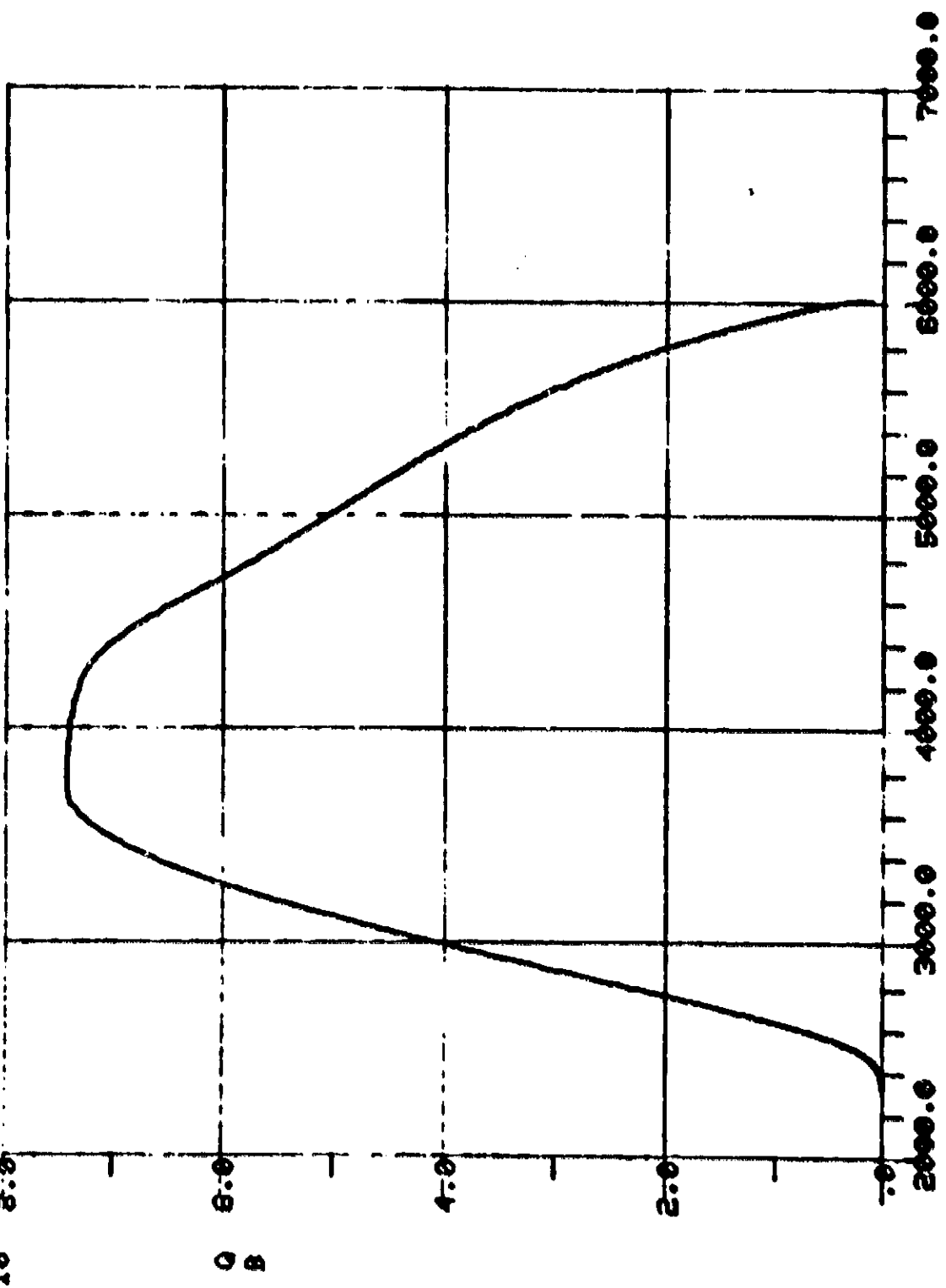
SO2P TRAJECTORIES

The following Titan atmospheric entry trajectories are included in this Appendix:

<u>Entry Velocity (m/sec)</u>	<u>Flight Path Angle (degrees)</u>	<u>Figures</u>
6,000	-22.5	A1 through A6
6,000	-26.5	A7 through A12
6,000	-30.5	A13 through A18
8,000	-23.0	A19 through A24
8,000	-28.0	A25 through A30
8,000	-33.0	A31 through A36
10,000	-23.0	A37 through A42
10,000	-28.0	A43 through A48
10,000	-32.5	A49 through A54
10,000	-33.0	A55 through A60
13,000	-23.5	A61 through A66
13,000	-26.0	A67 through A72
13,000	-29.0	A73 through A78

10:10 JUN 09, '89

10 3 U-5220; GAMMA--22.5



UA

APPENDIX A
FIGURE A-2

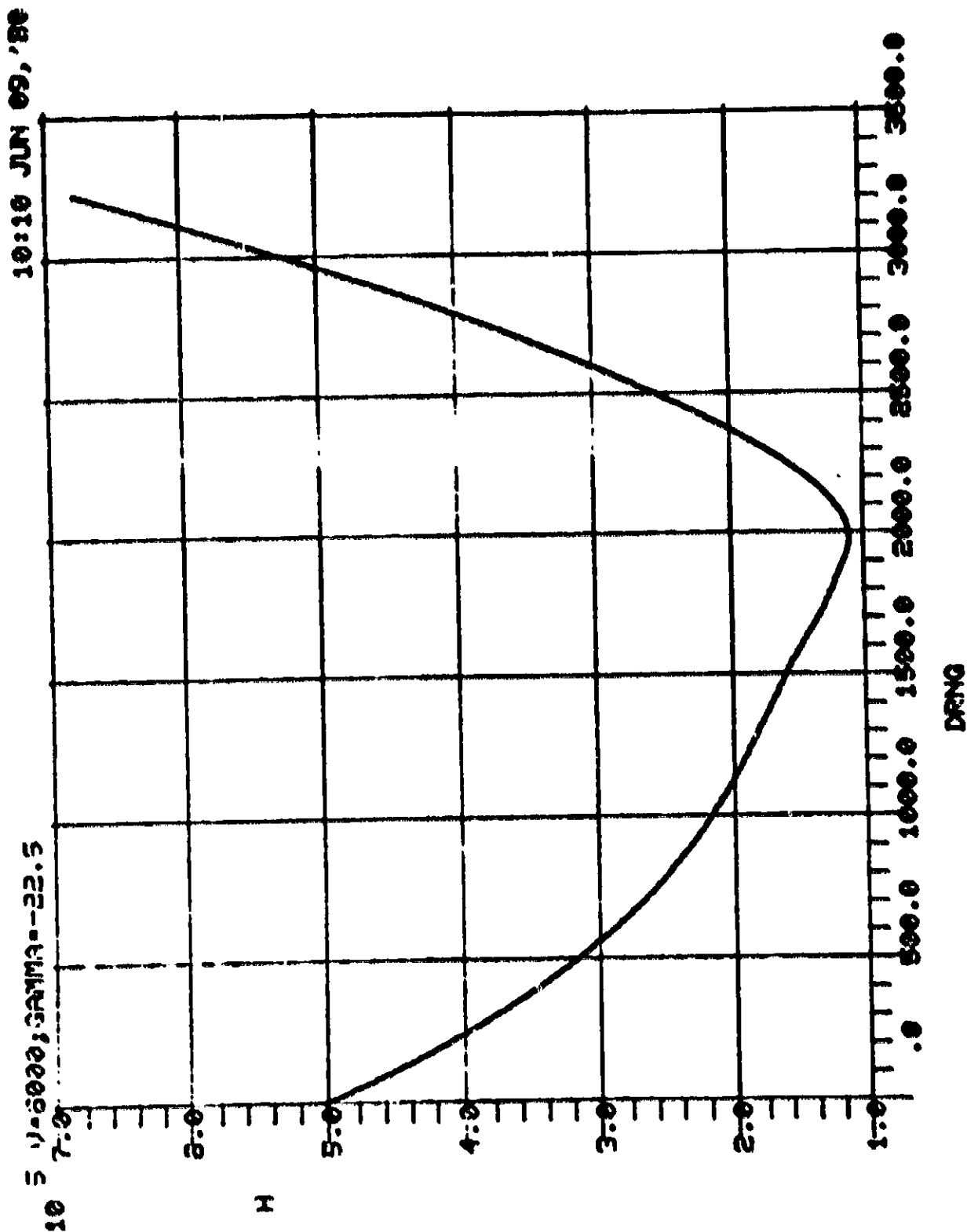


FIGURE A-1

10:10 JUN 09, '80

10 5 U=6000; GAMMA=-22.5
7.0

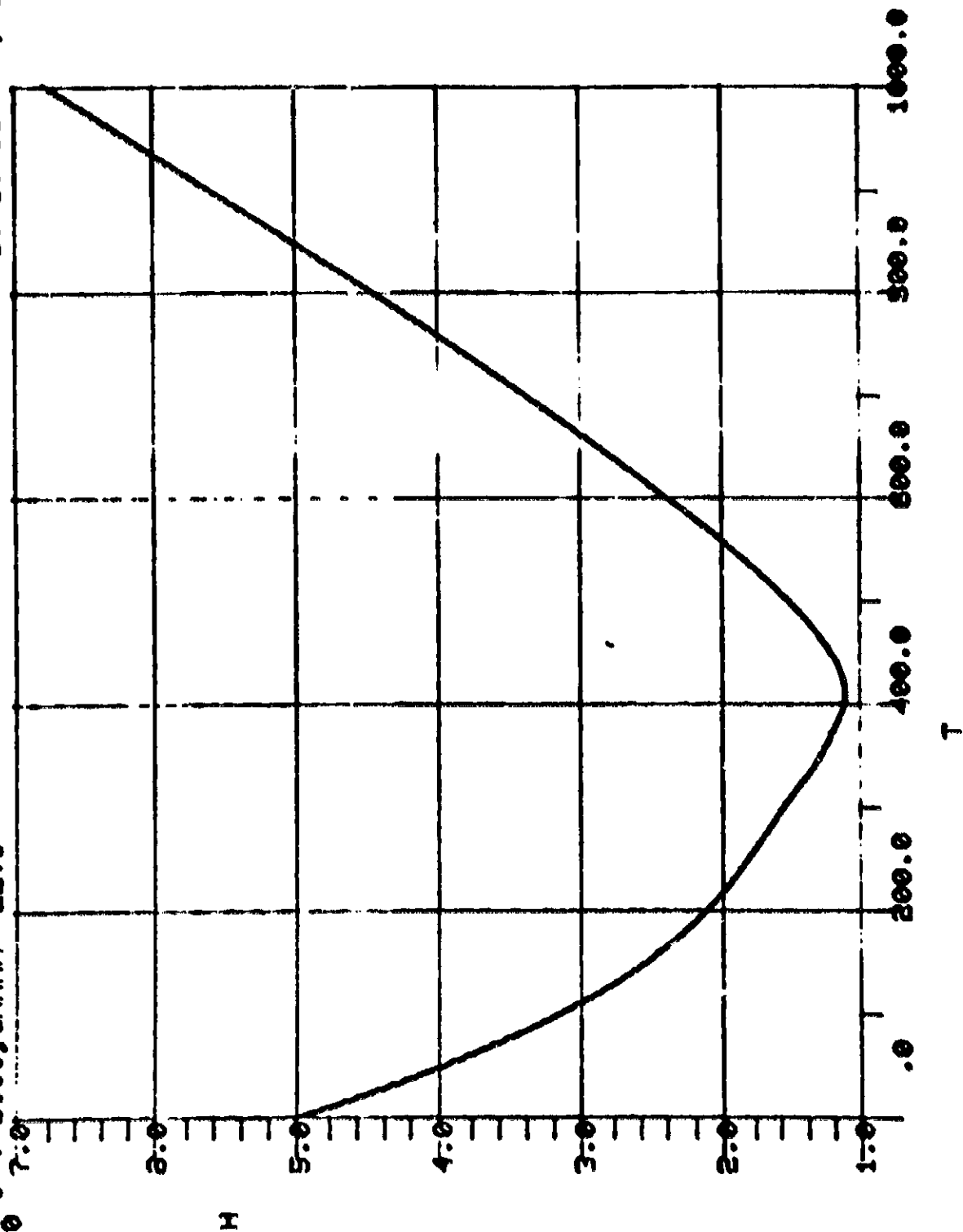


FIGURE A-1

10:10 JUN 09, '30

10 3 4.5000; GAMMA = 22.5

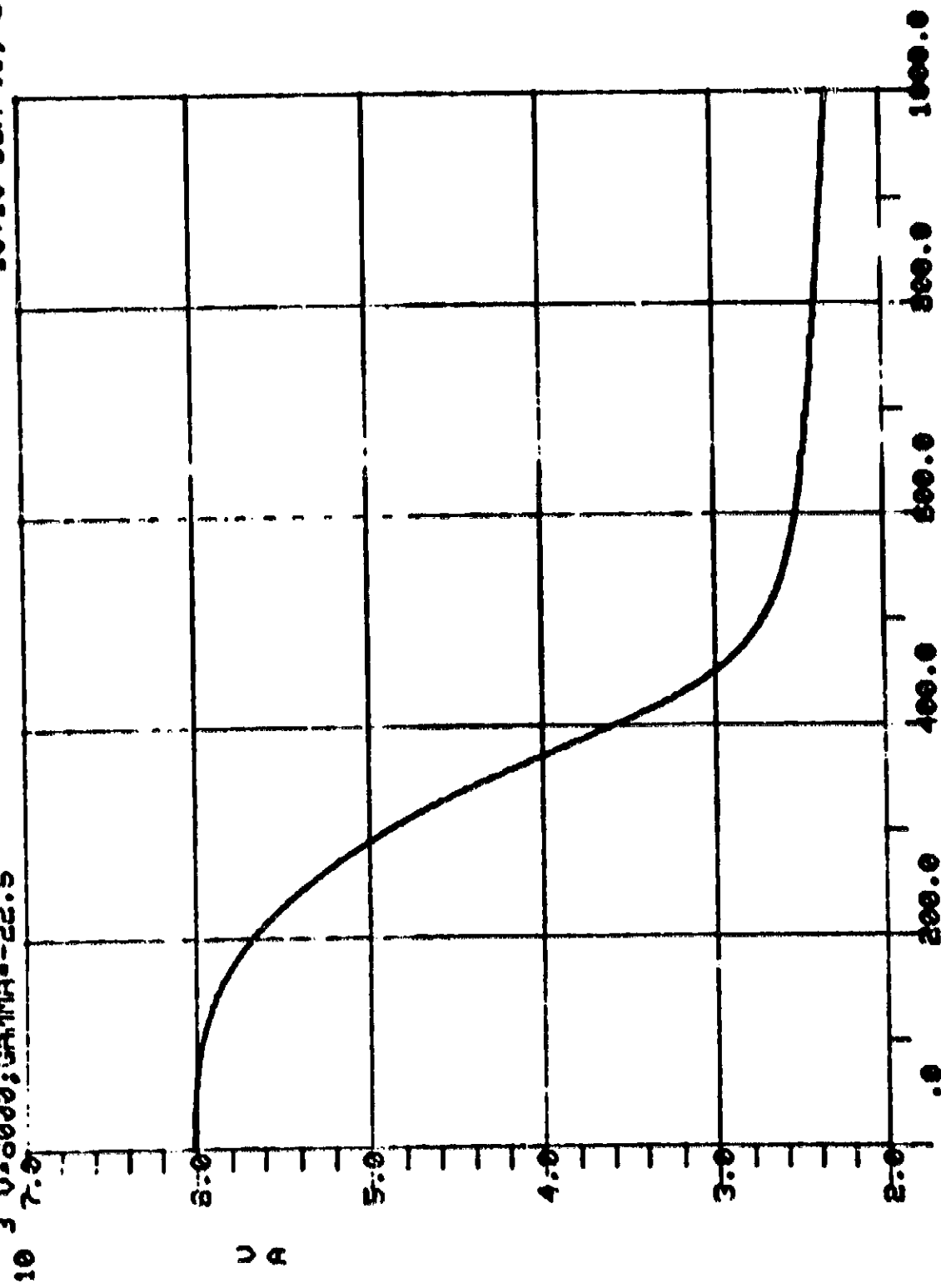


FIGURE A-4

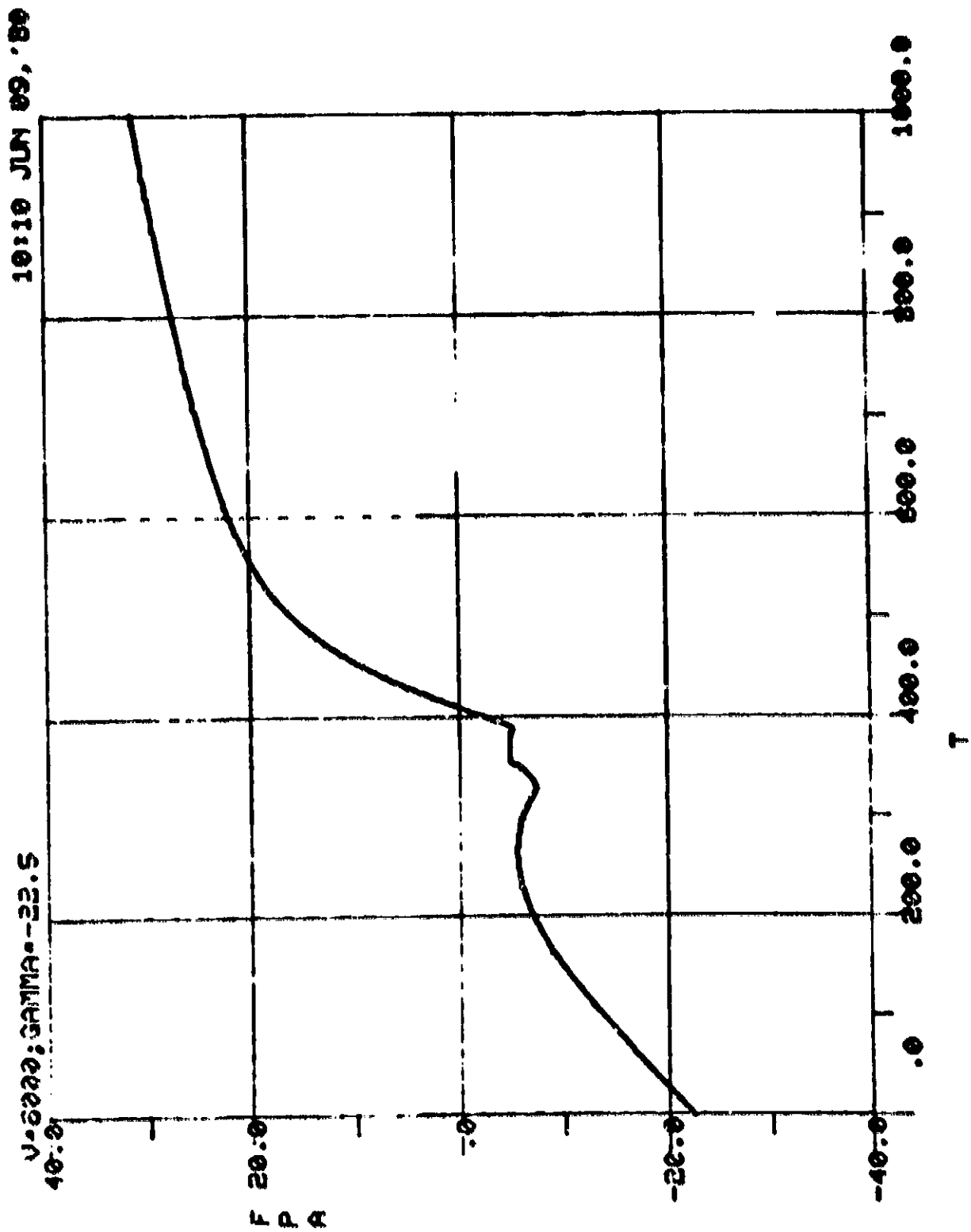


FIGURE 4-7

10:10 JUN 09, '50

V-5000; GAMMA=-22.5

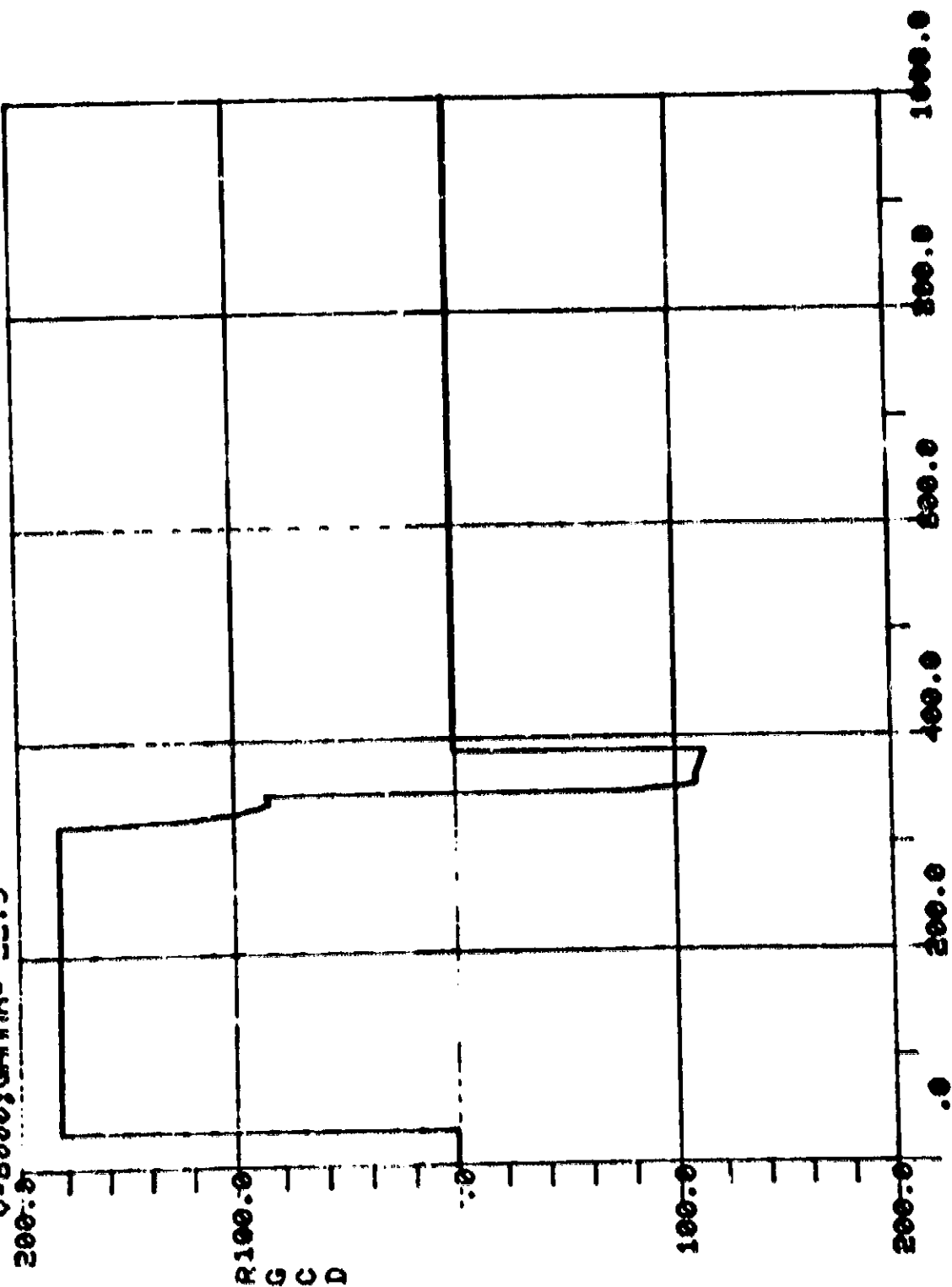


FIGURE A-5

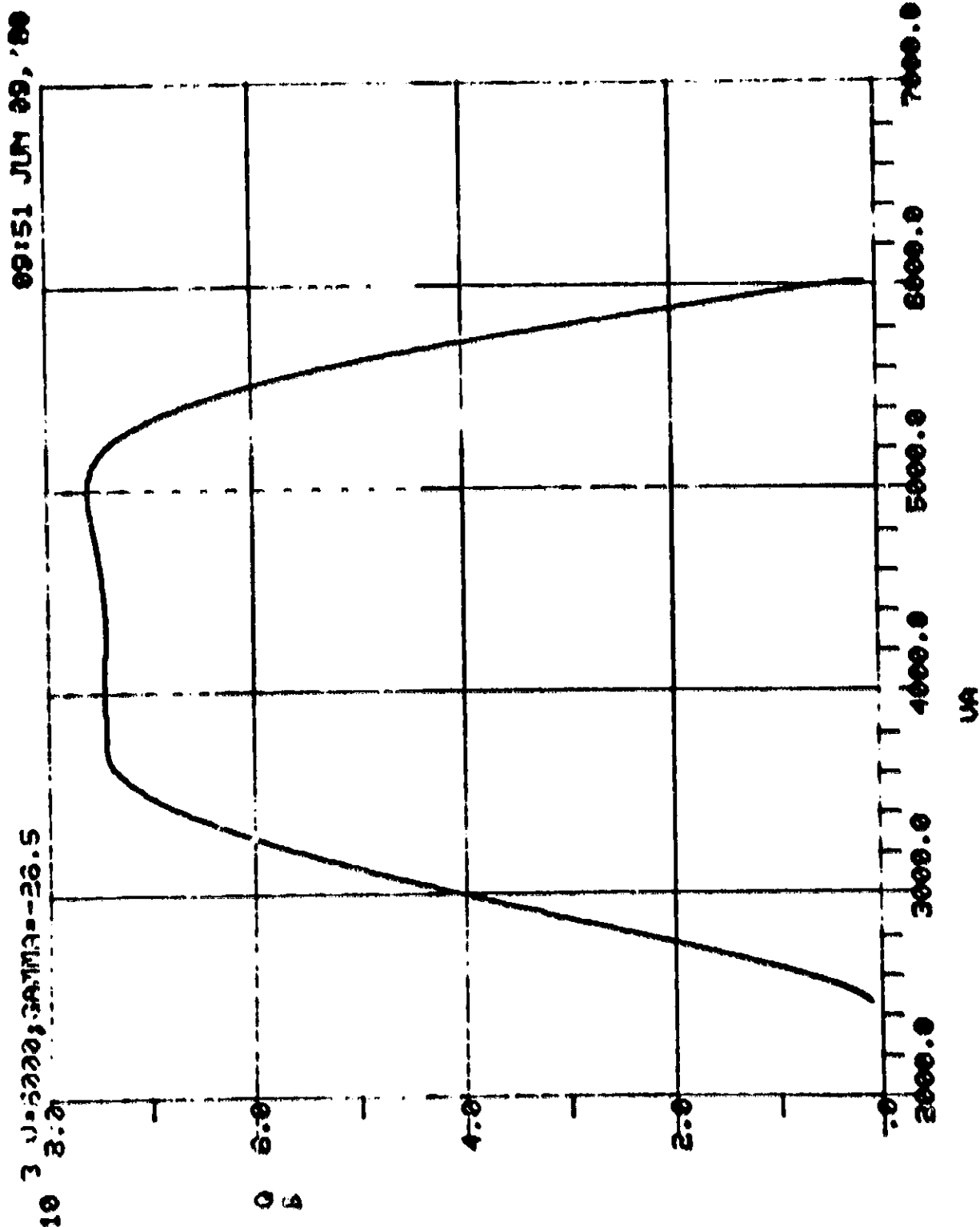
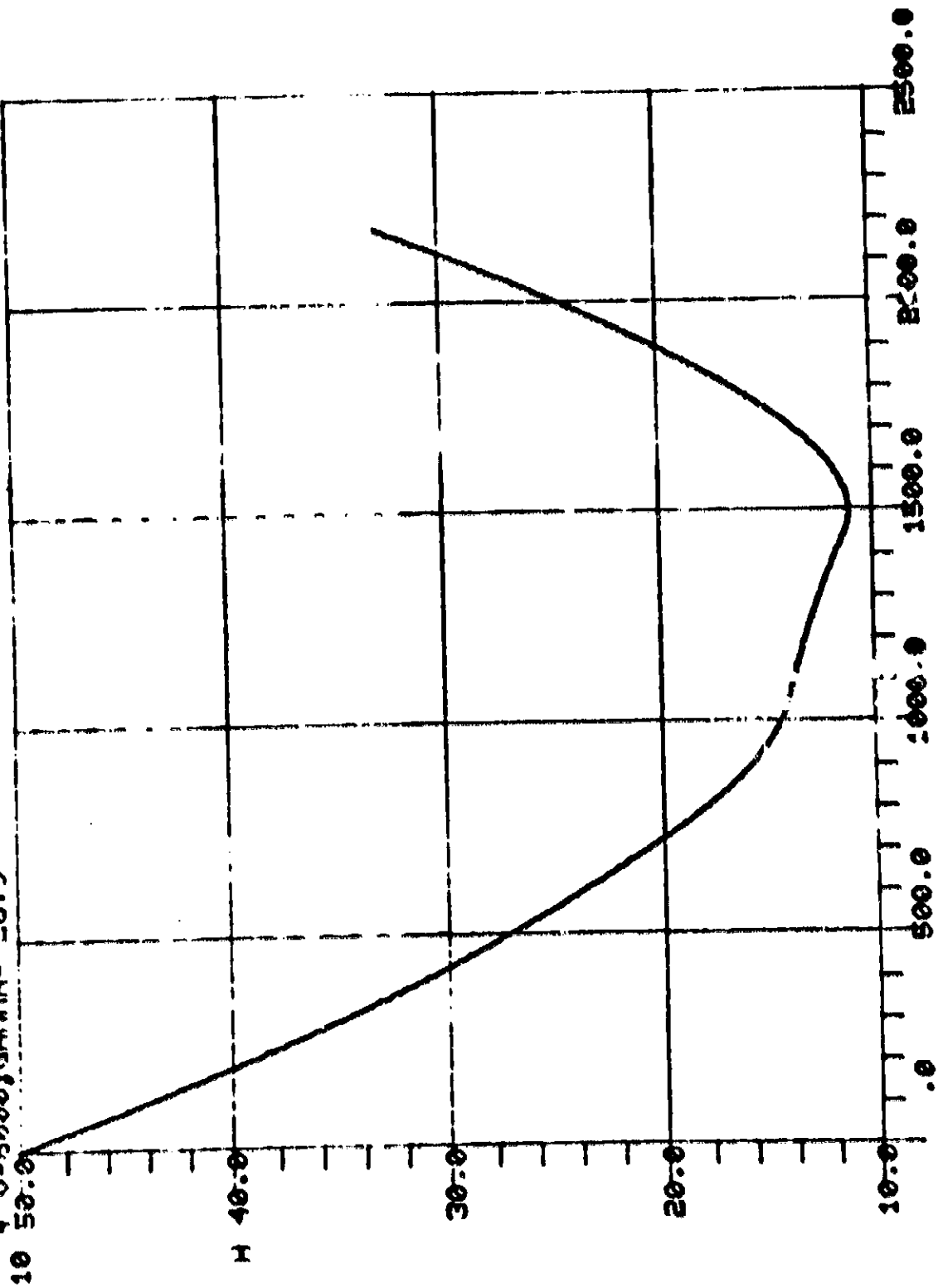


FIGURE A-7

09:51 JUN 09, '80

4 0.0000, GAMMA = -26.5



DRNG

FIGURE 4.5

09:51 JUN 09, '80

10 50.0
H 40.0
30.0
20.0
10.0
0.0

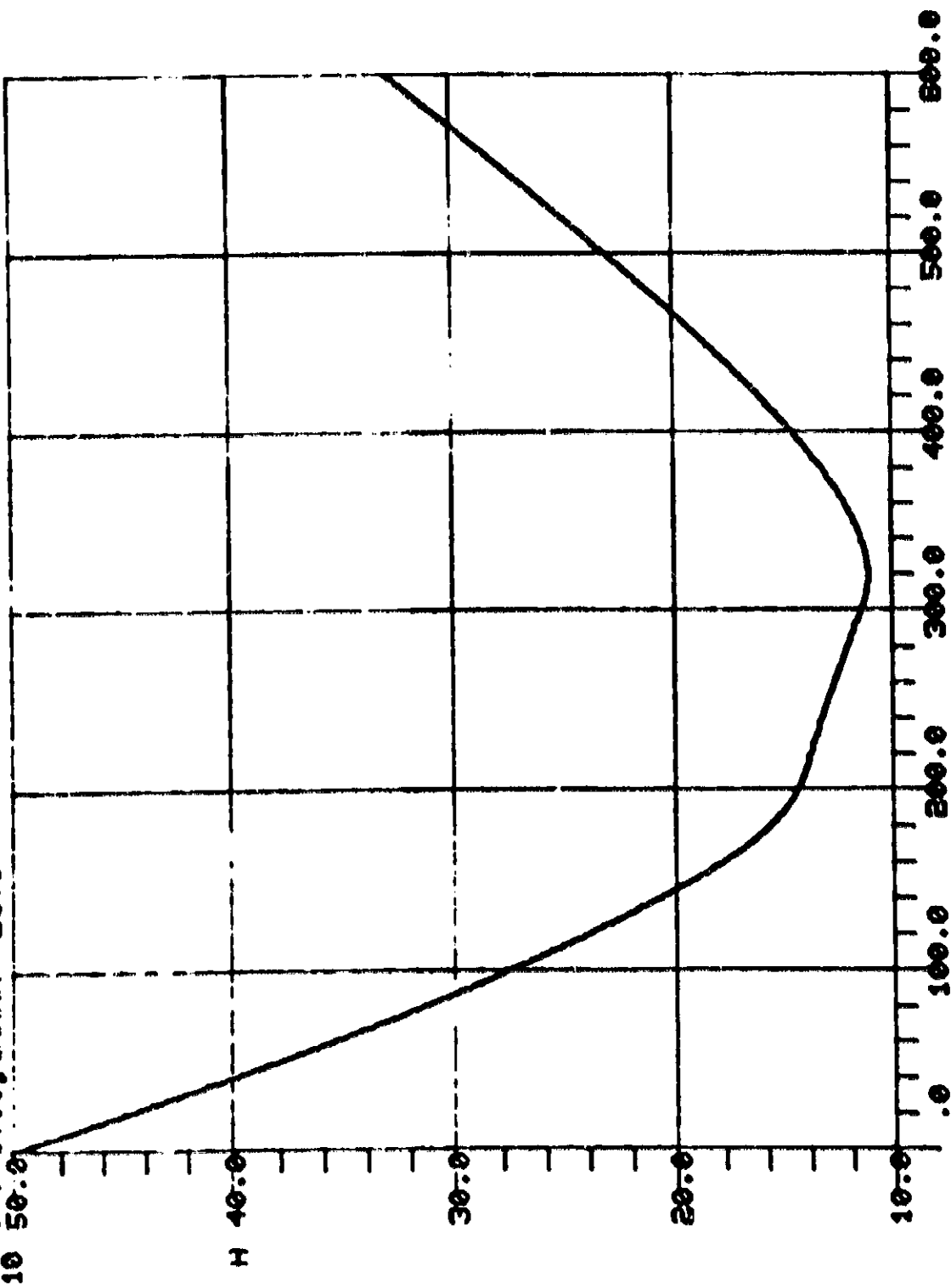


FIGURE A-3

09:51 JUN 09, '80

10 3 U-5000, GAMMA=-26.5
7.0

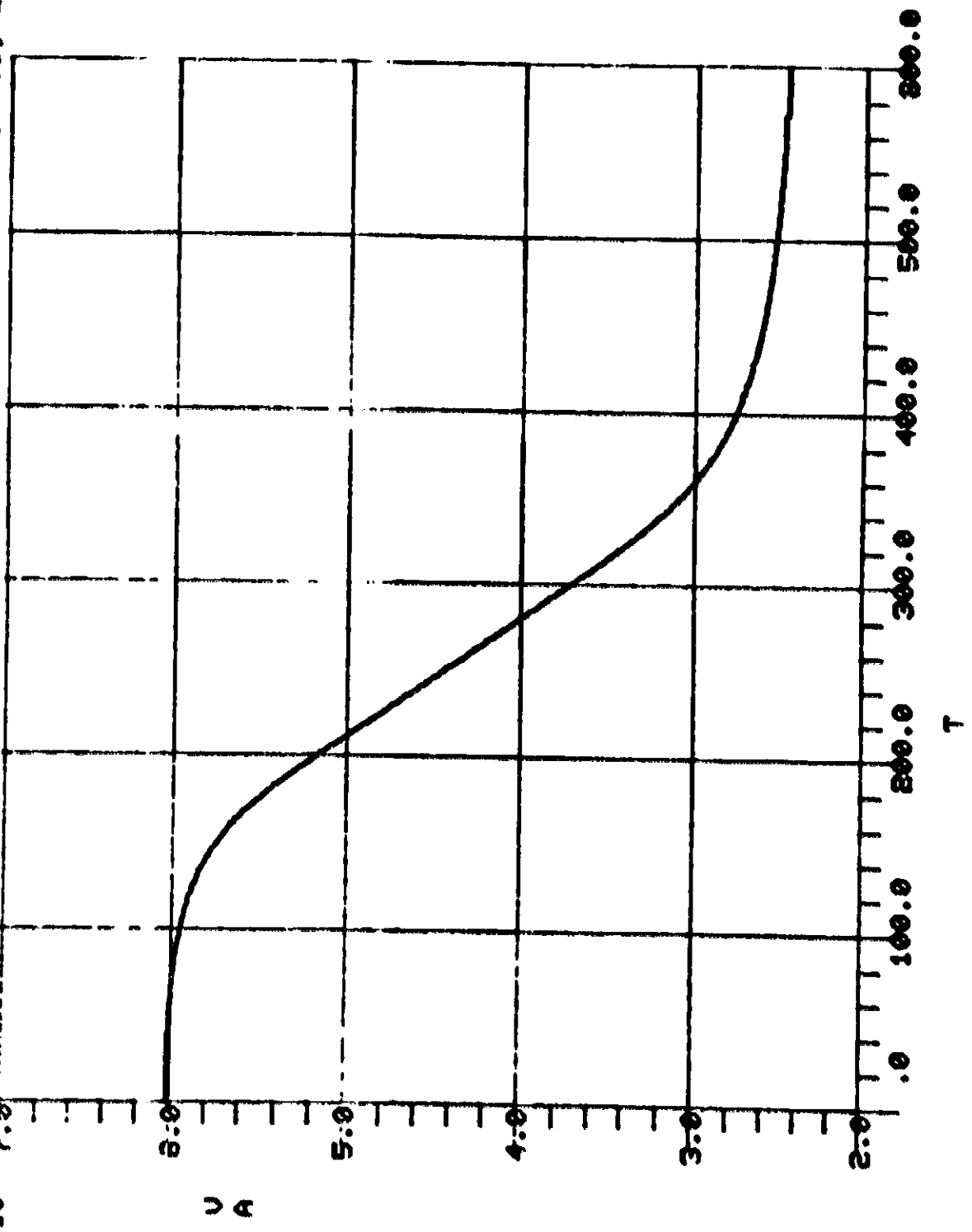


FIGURE A-10

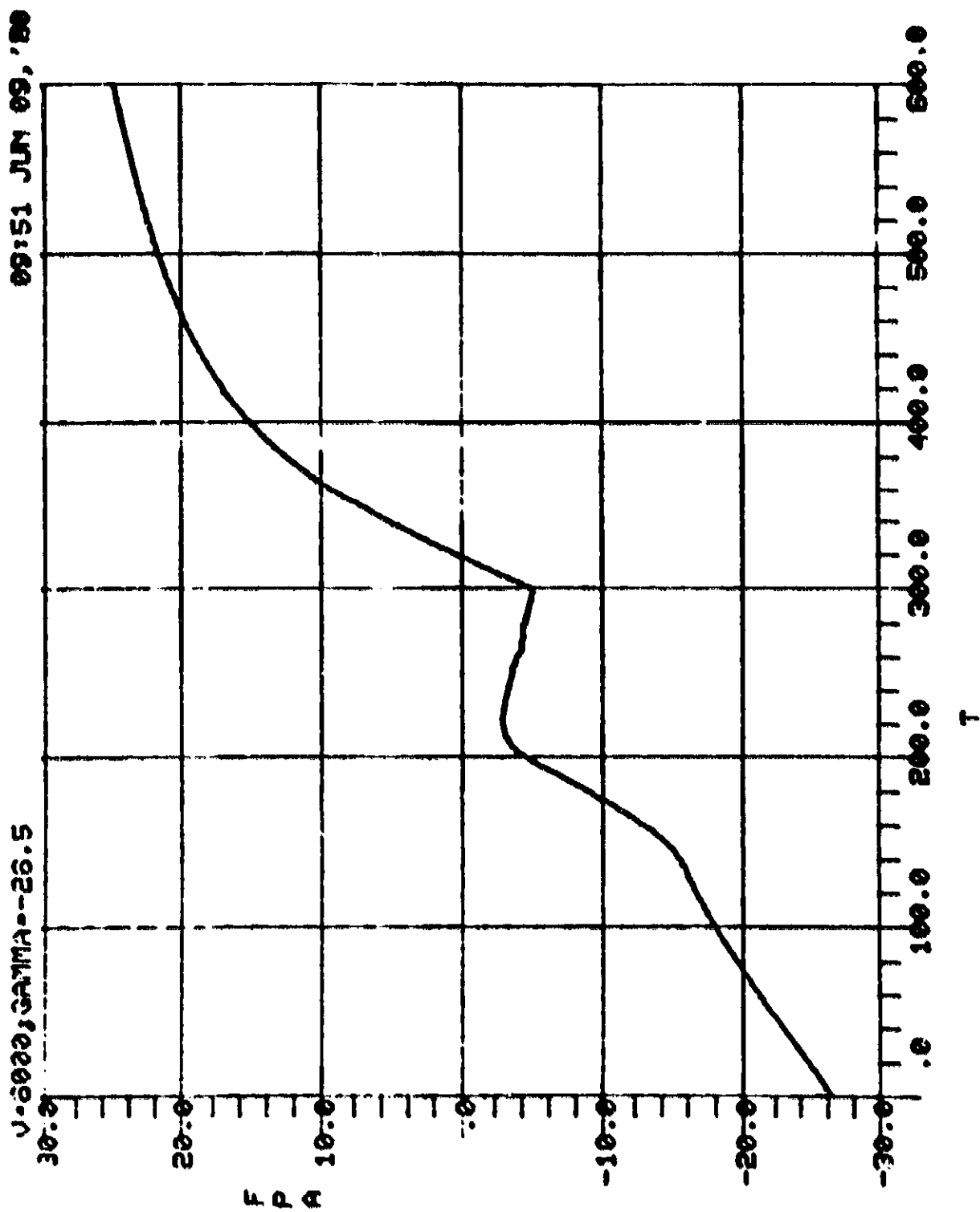


FIGURE A-11

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V-2000; GAMMA=-26.5

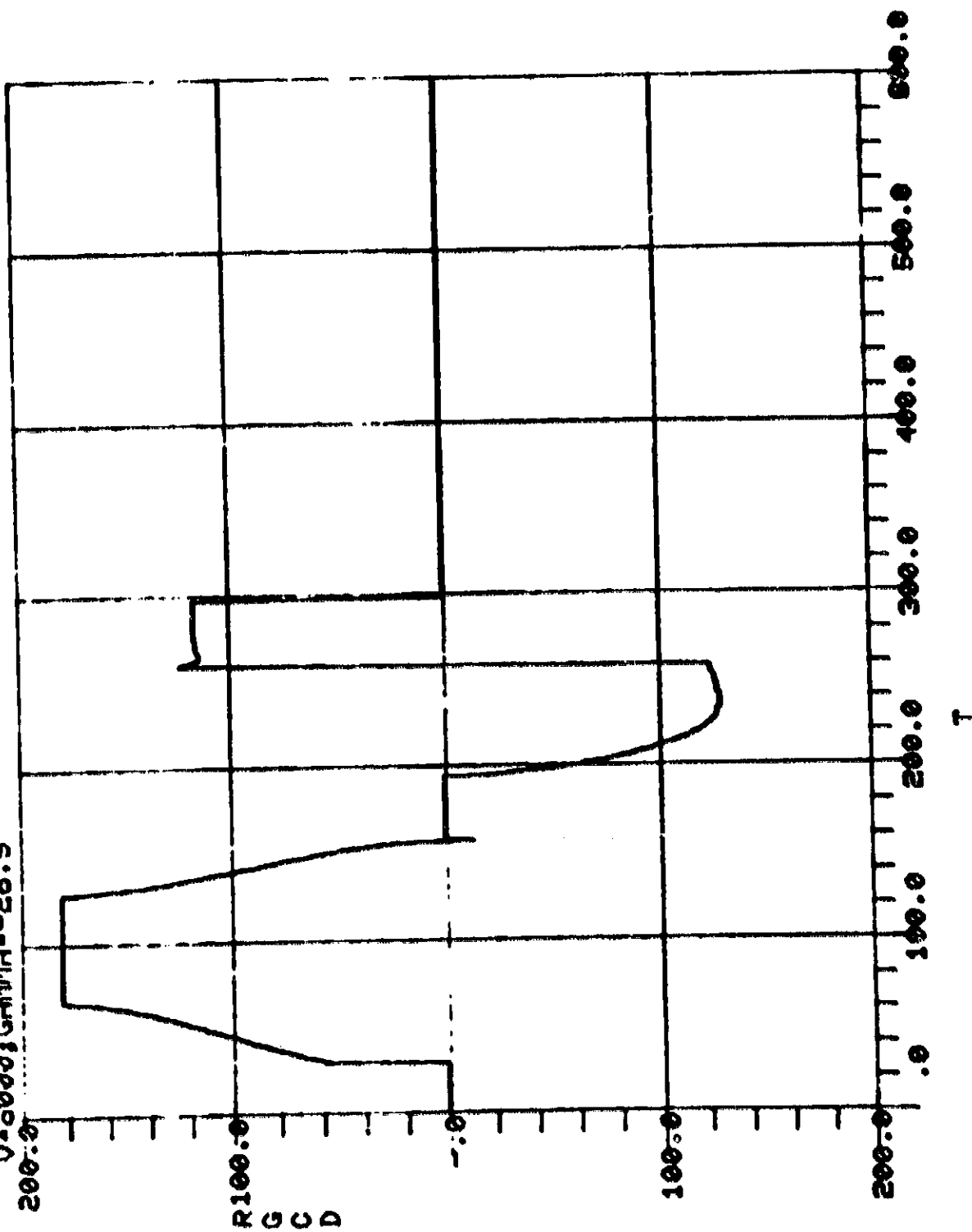


FIGURE A-11

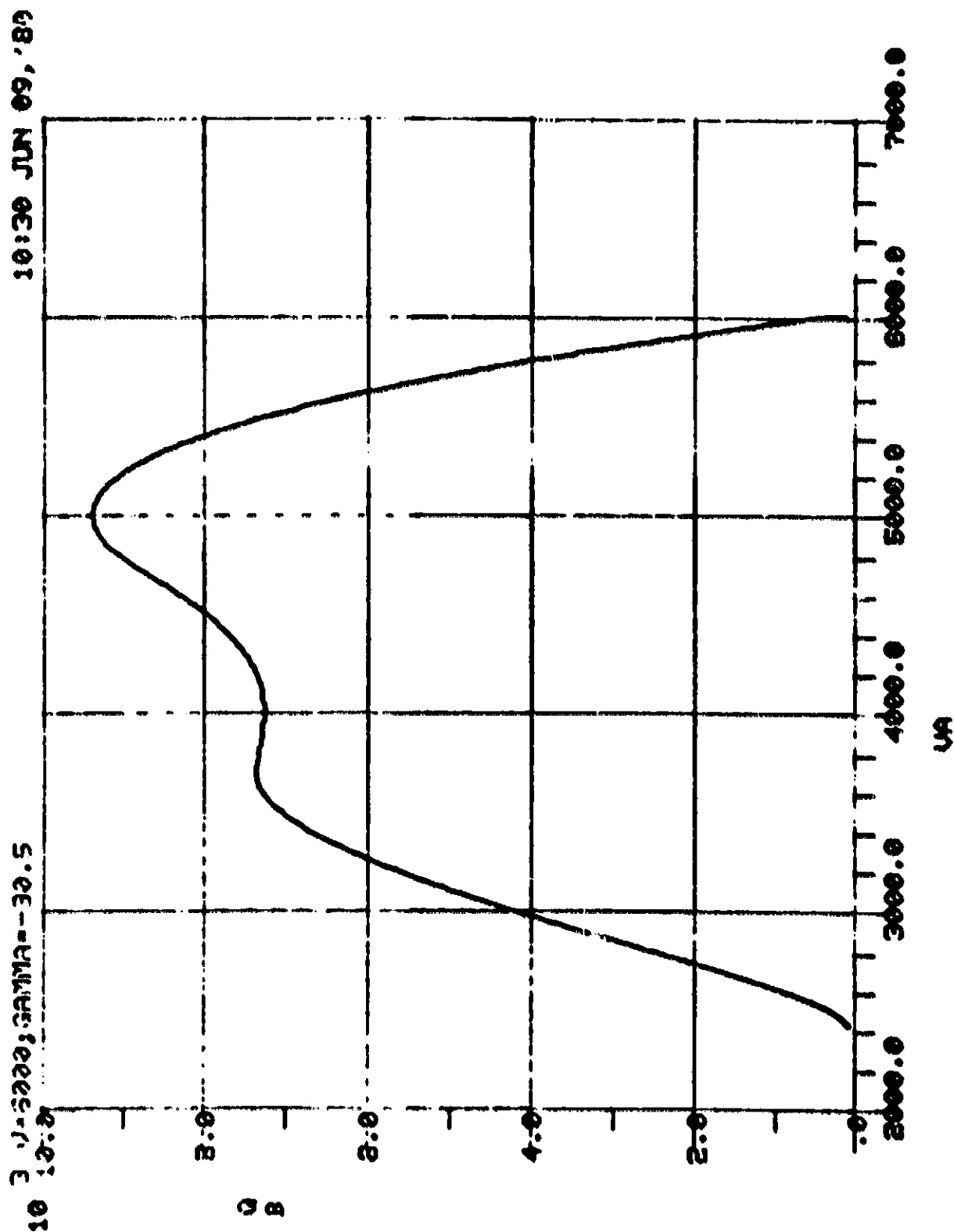
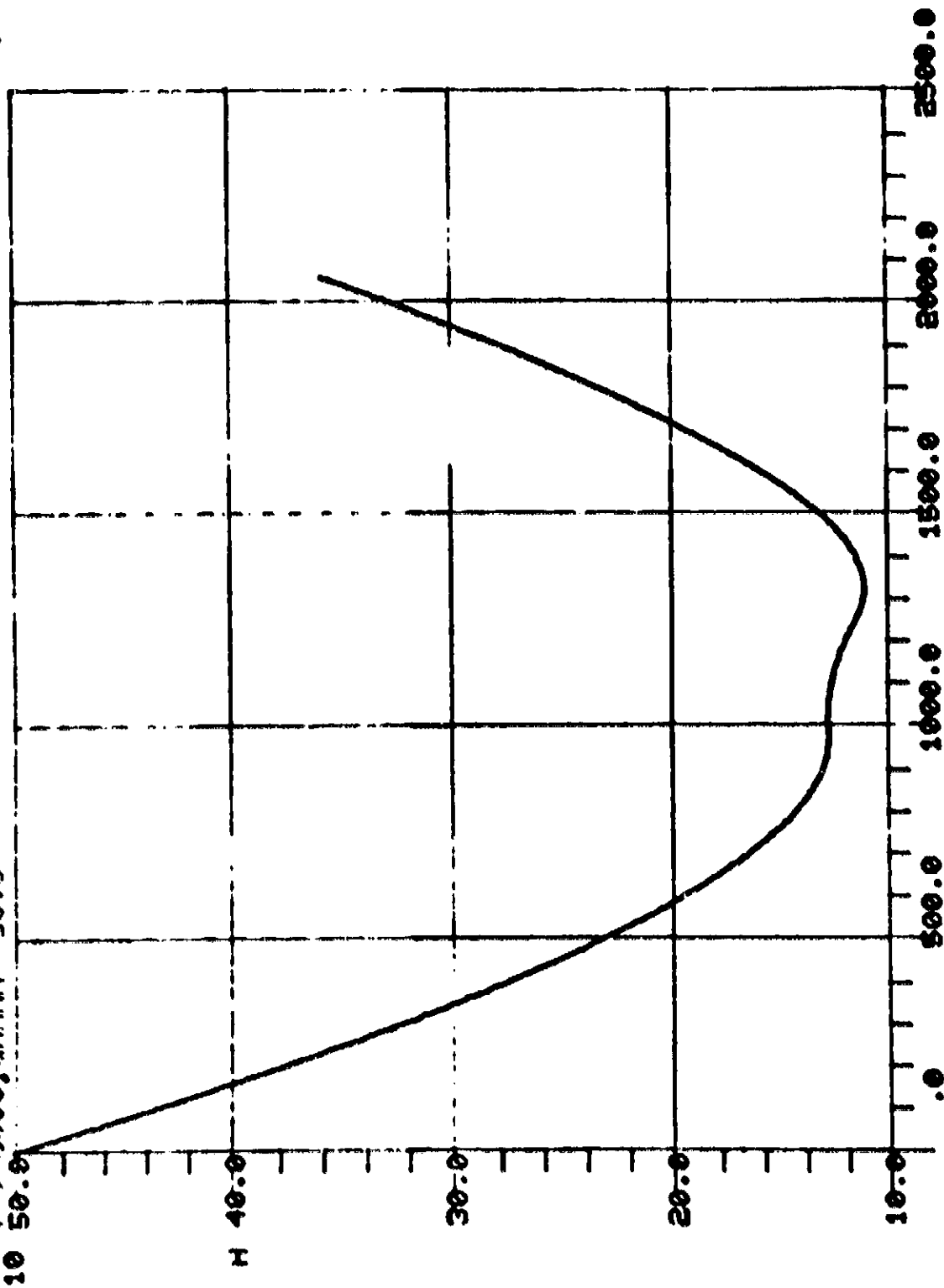


FIGURE A-13

10:30 JUN 09, '80

4 U=3220; GAMMA=-30.5

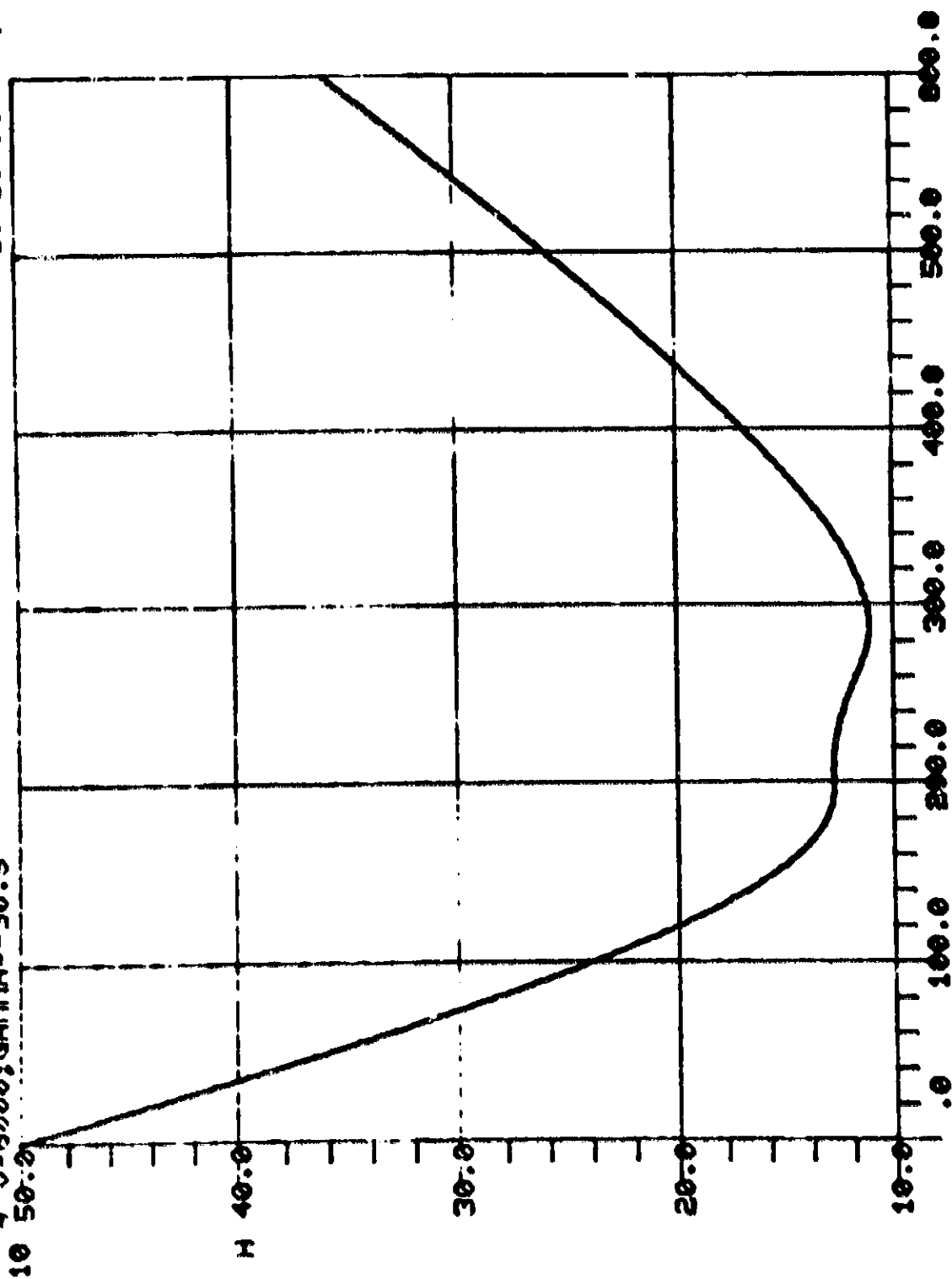


DRNG

FIGURE 1-12

10:30 JUN 09, '80

10 4 U-3320; GAMMA=-30.5

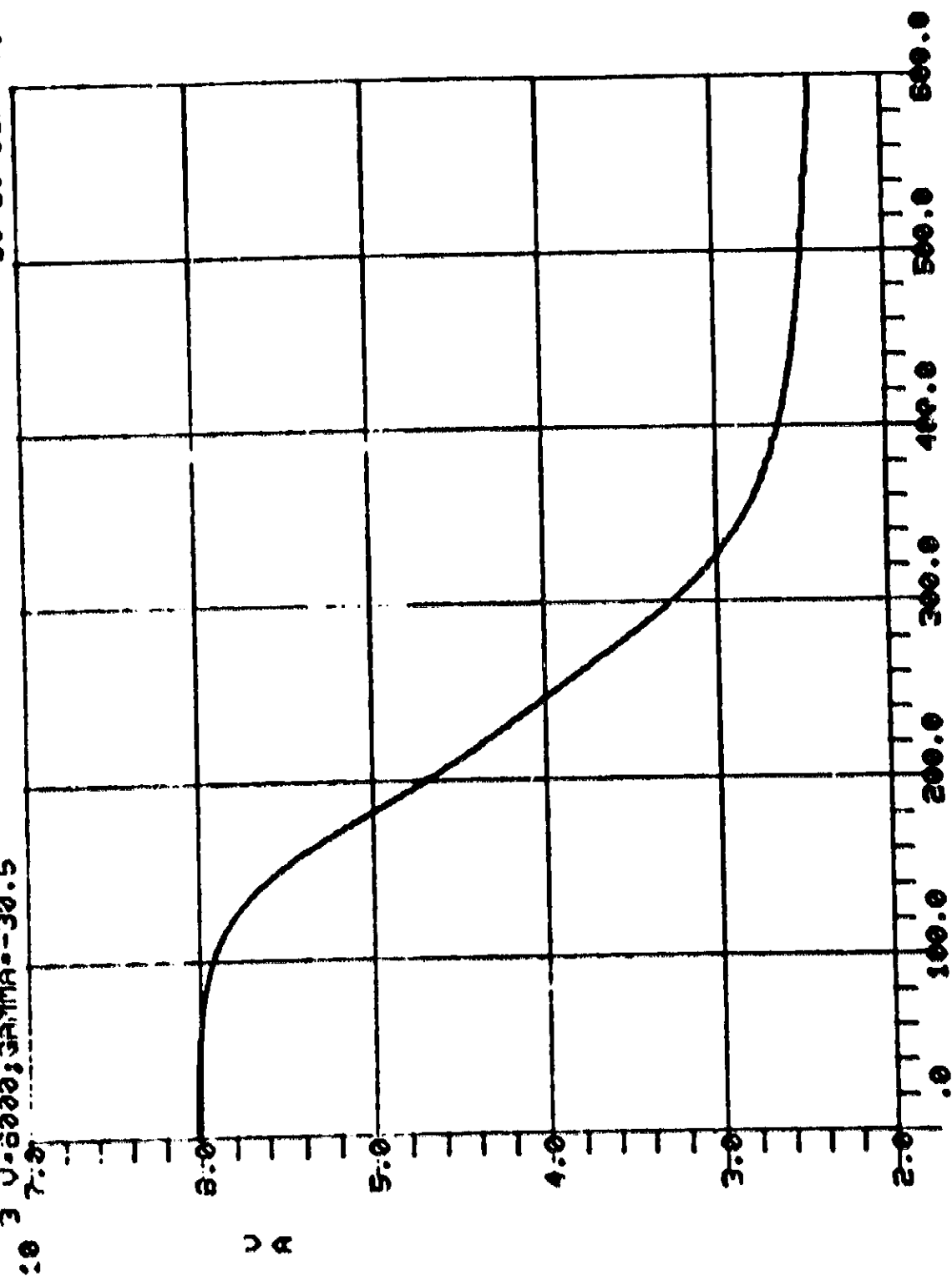


T

FIGURE A-15

10:30 JUN 09 '80

3 U-6000; GAMMA-30.5



T

FIGURE 1-16

10:30 JUN 09, '80

V.6000; GAMMA-30.5

40.0

F P A

20.0

-20.0

-40.0

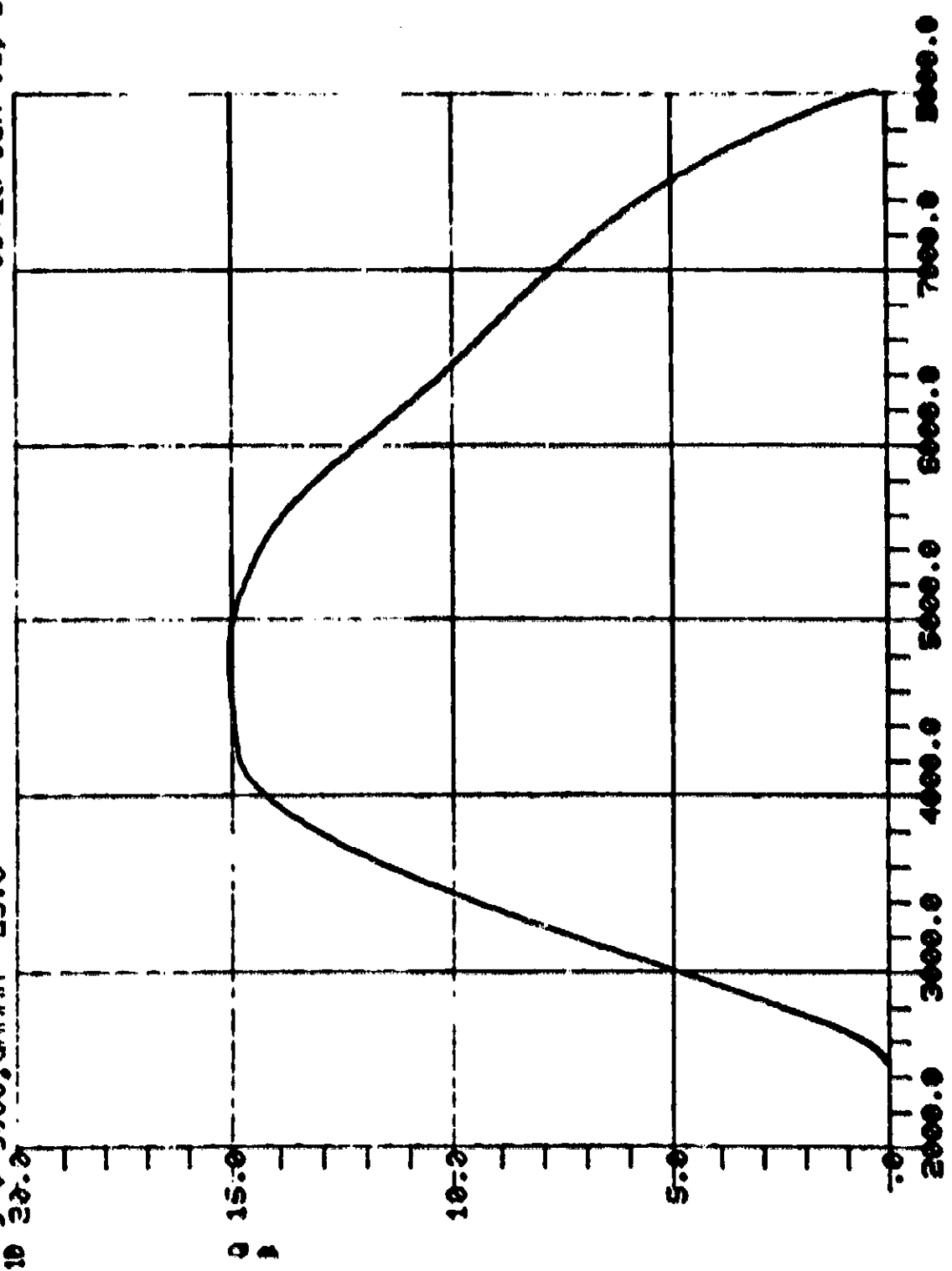
0 100.0 200.0 300.0 400.0 500.0 600.0

T

FIGURE A-17

3 U-3900; GAMMA-23.0
10 23.0

09:28 JUN 06, '60

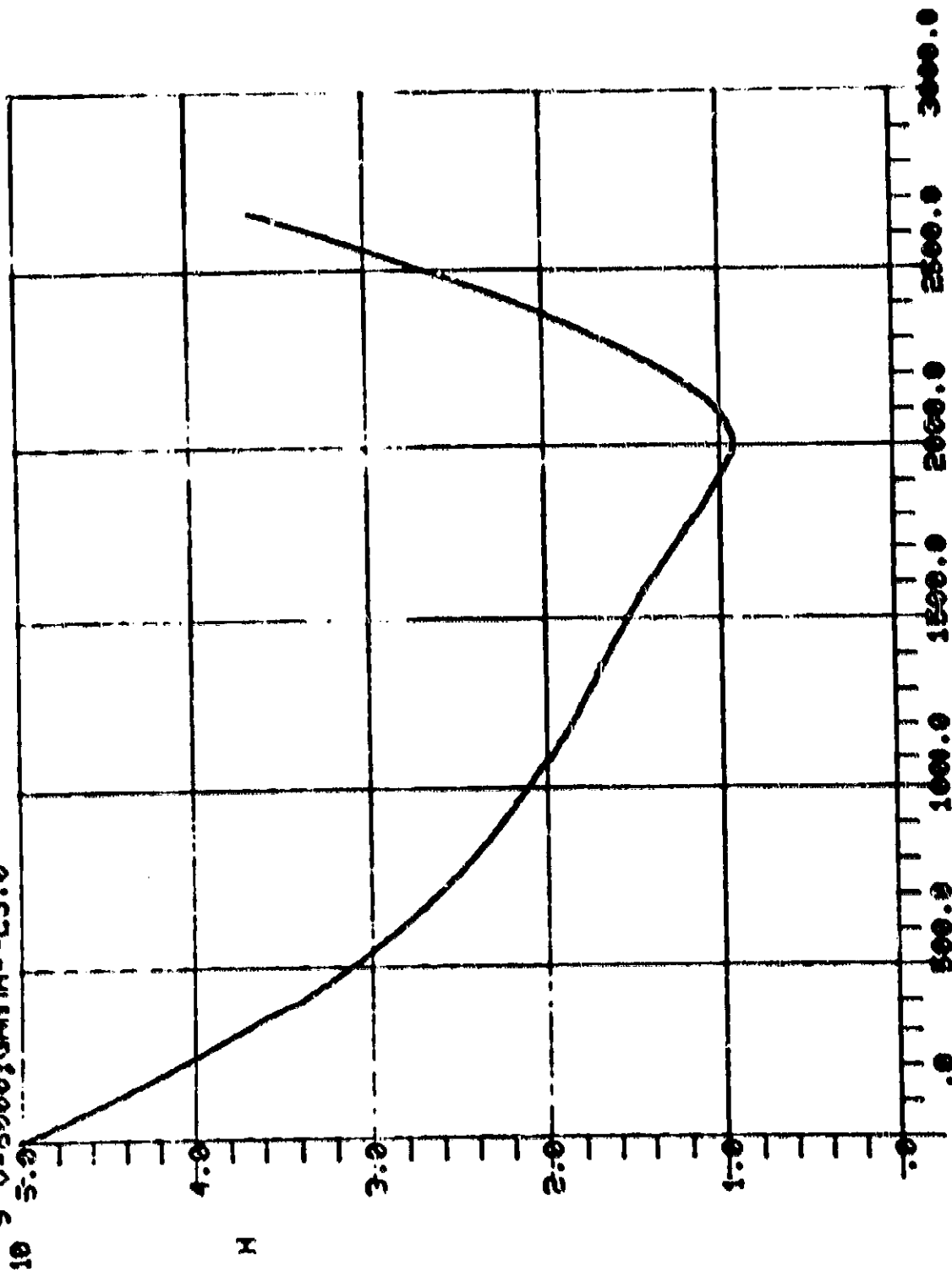


UM

FIGURE 1-10

09:28 JUN 06, '80

10 5.0
5 U=3920; GAMMA=-23.0



DANG

FIGURE A-20

10 5 0-3000; GAMMA=-23.0

09:28 JUN 06, '89

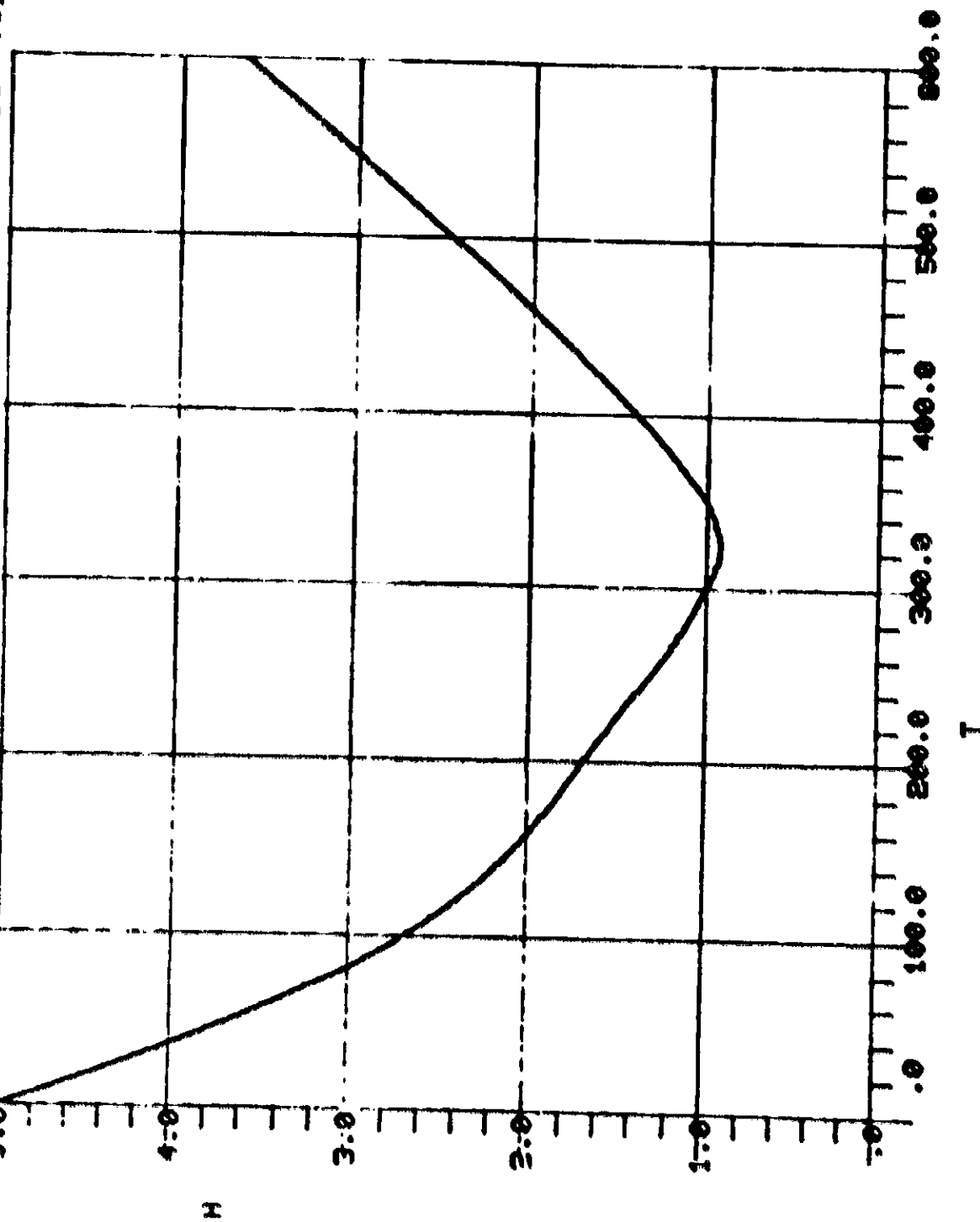


FIGURE A-20

09:28 JUN 06, '80

10 3 U=3000; GAMMA=-23.0

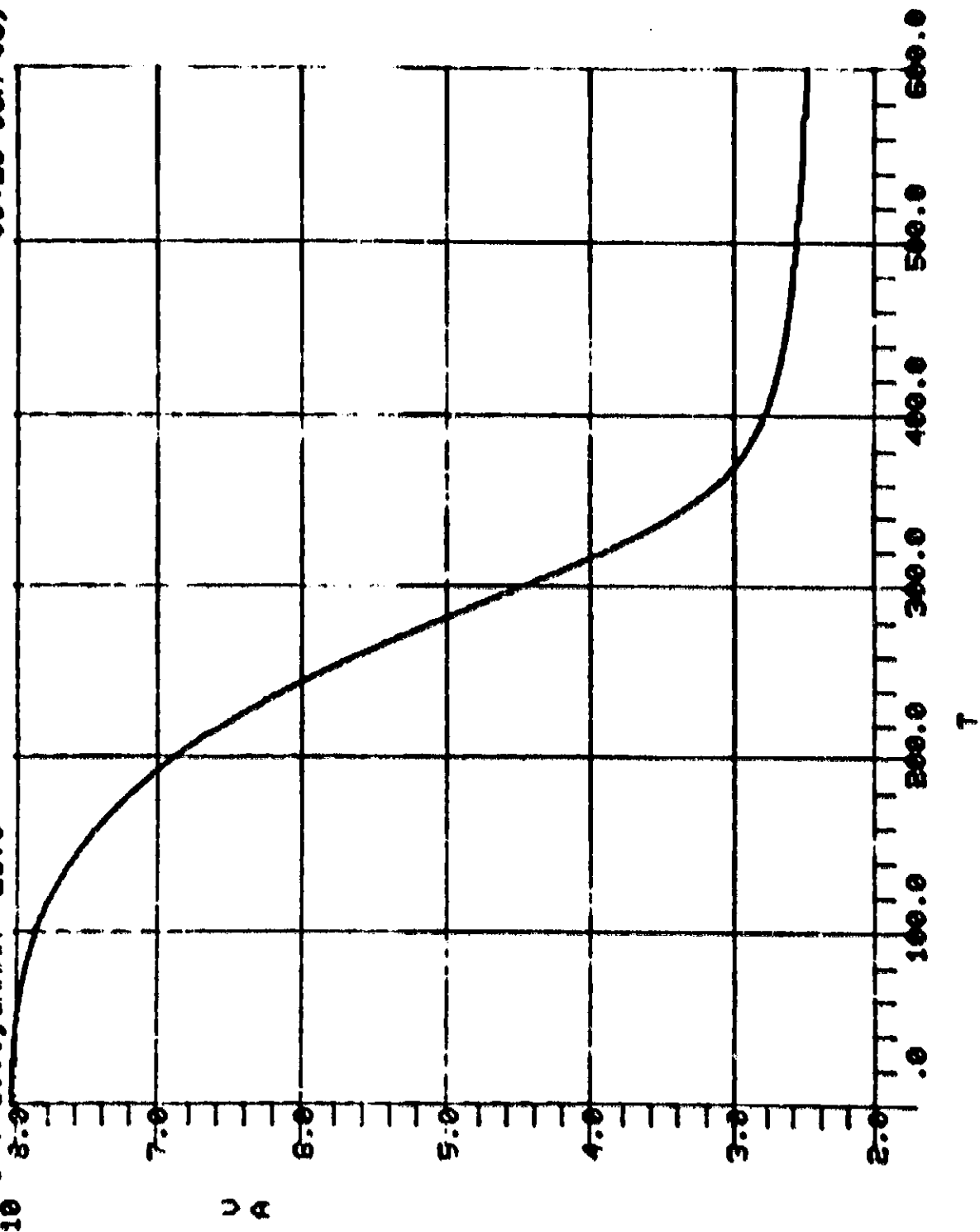


FIGURE 1-22

09:28 JUN 66, '80

V=3000; GAMMA=-23.0

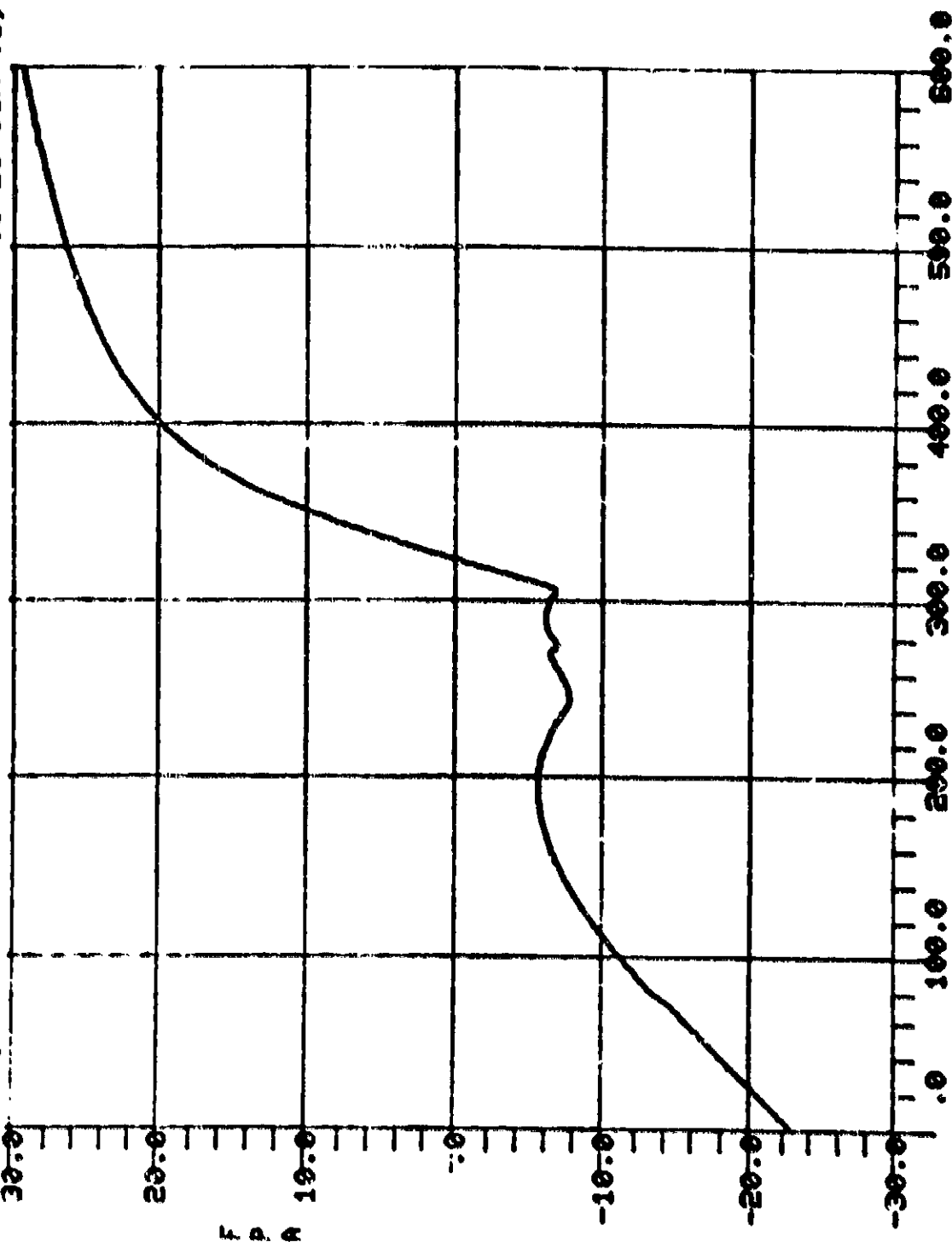


FIGURE A-23

09:28 JUN 06, '80

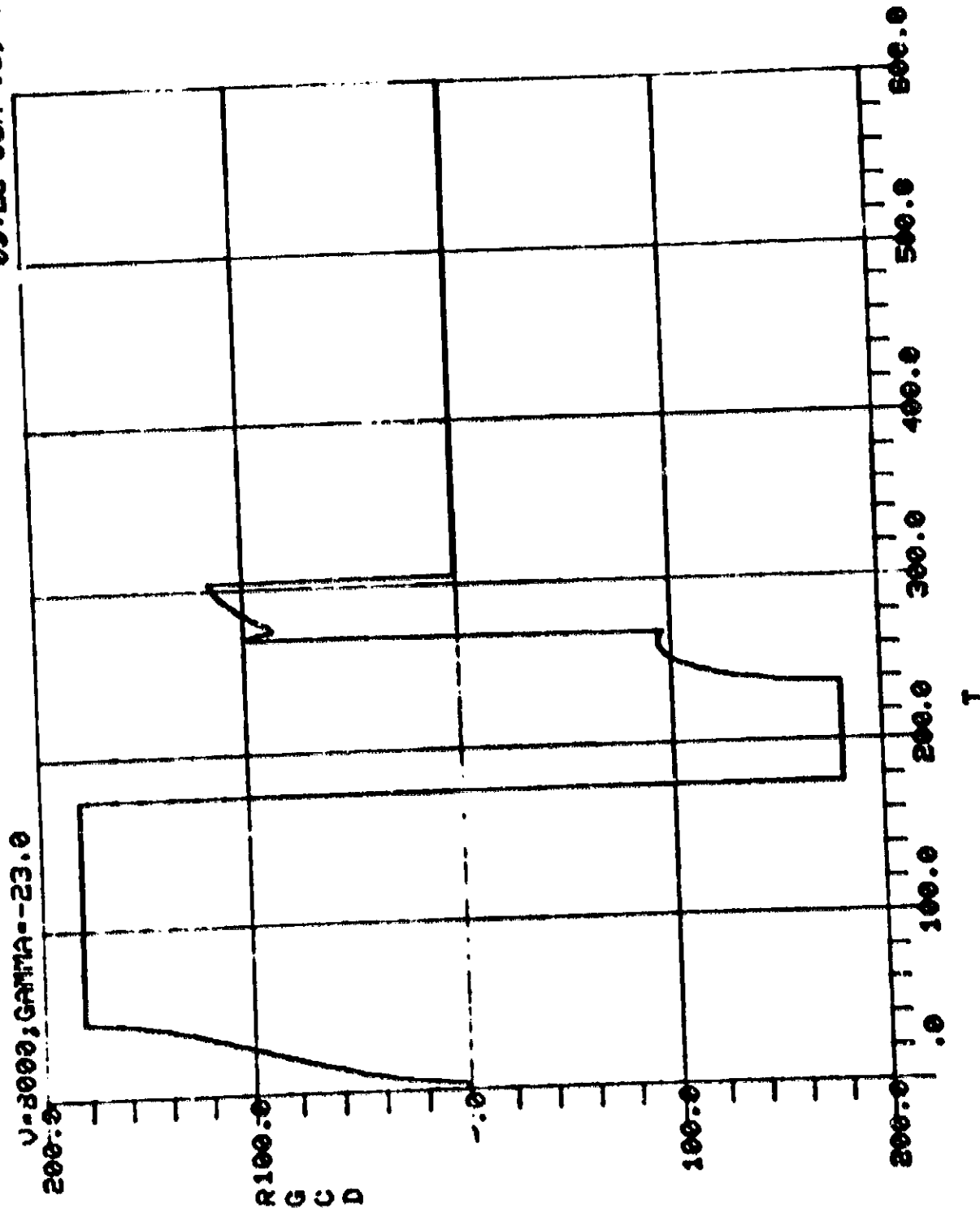


FIGURE A-24

09:05 JUN 06, '80

3 V-3300; GAMMA=-28.0

10 20.0

0 15.0

B

10.0

5.0

2000.0 3000.0 4000.0 5000.0 6000.0 7000.0 8000.0

UA

FIGURE A-25

09:05 JUN 06, '80

10 5 U-3000; GAMMA=-28.0

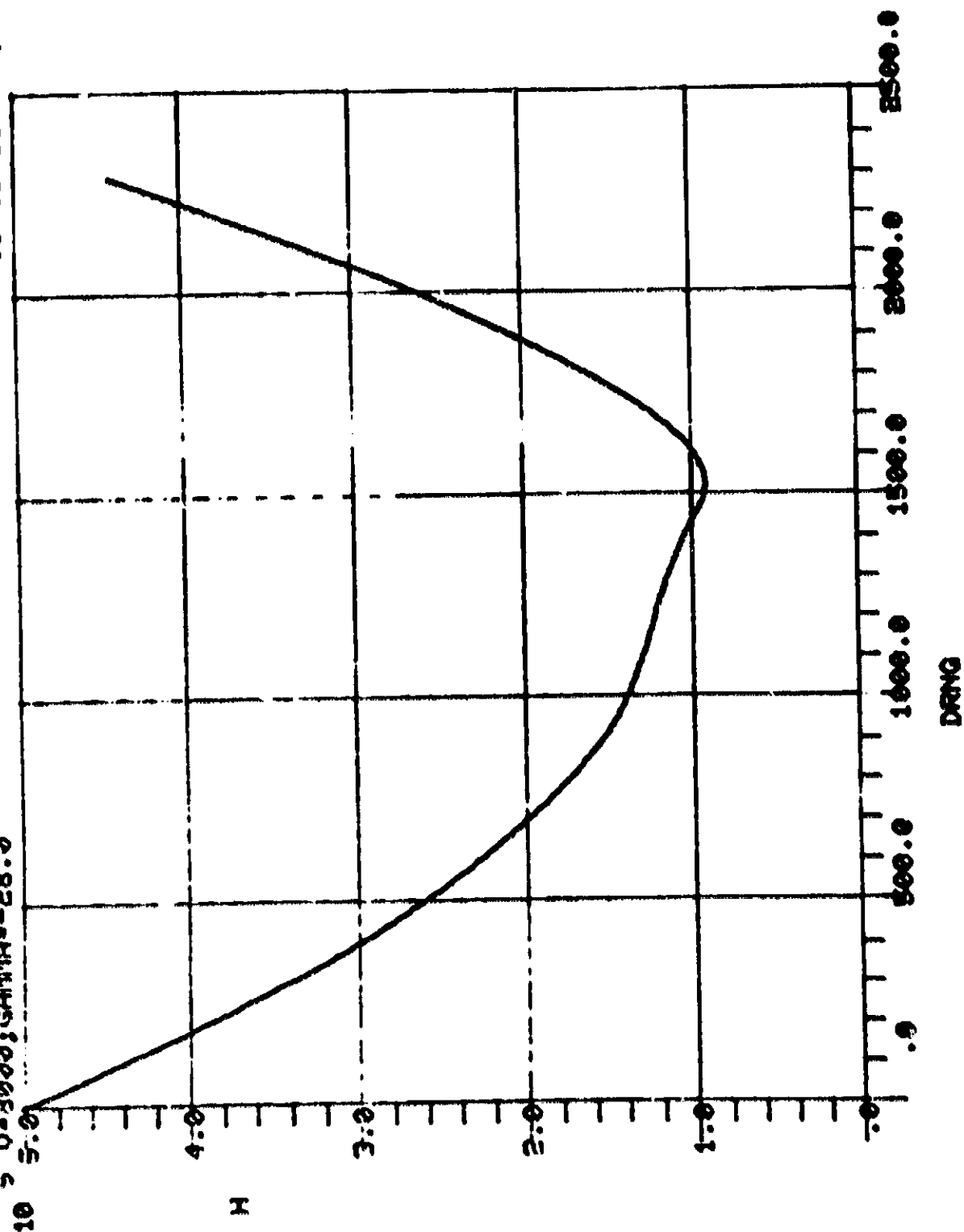


FIGURE A-25

39:05 JUN 06, '80

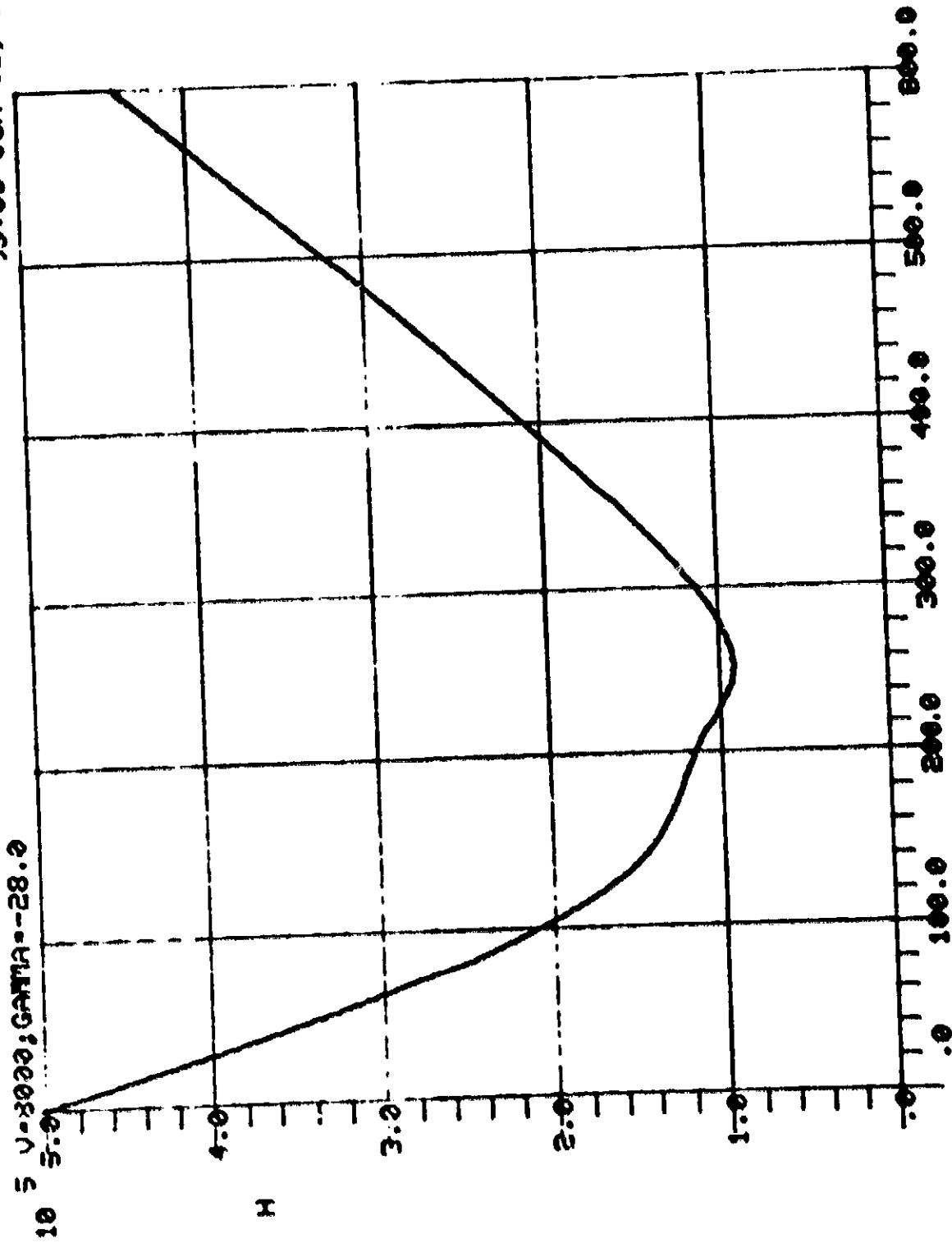


FIGURE 1.07

09:05 JUN 06, '80

10 3 U-3920; GAMMA=-28.0

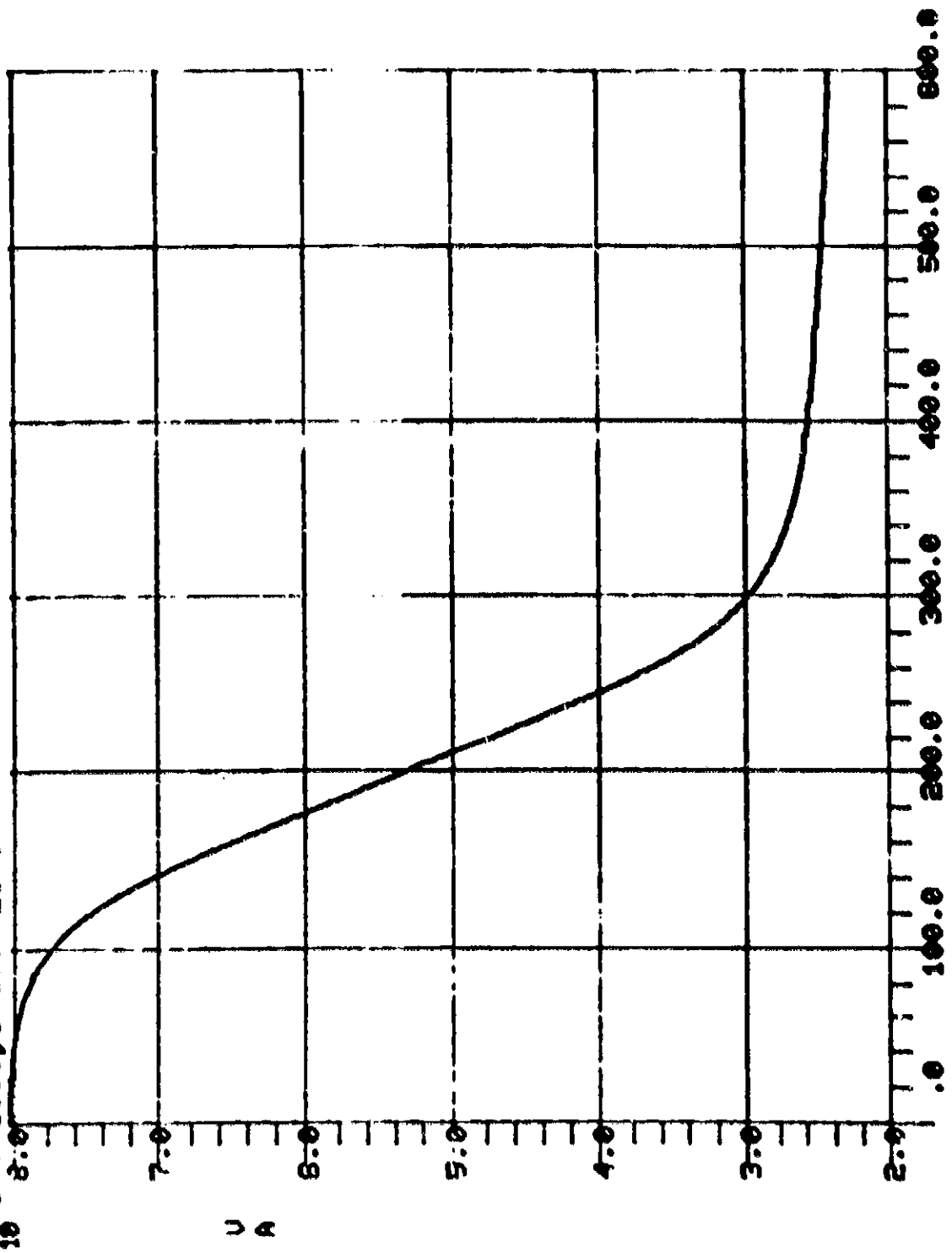
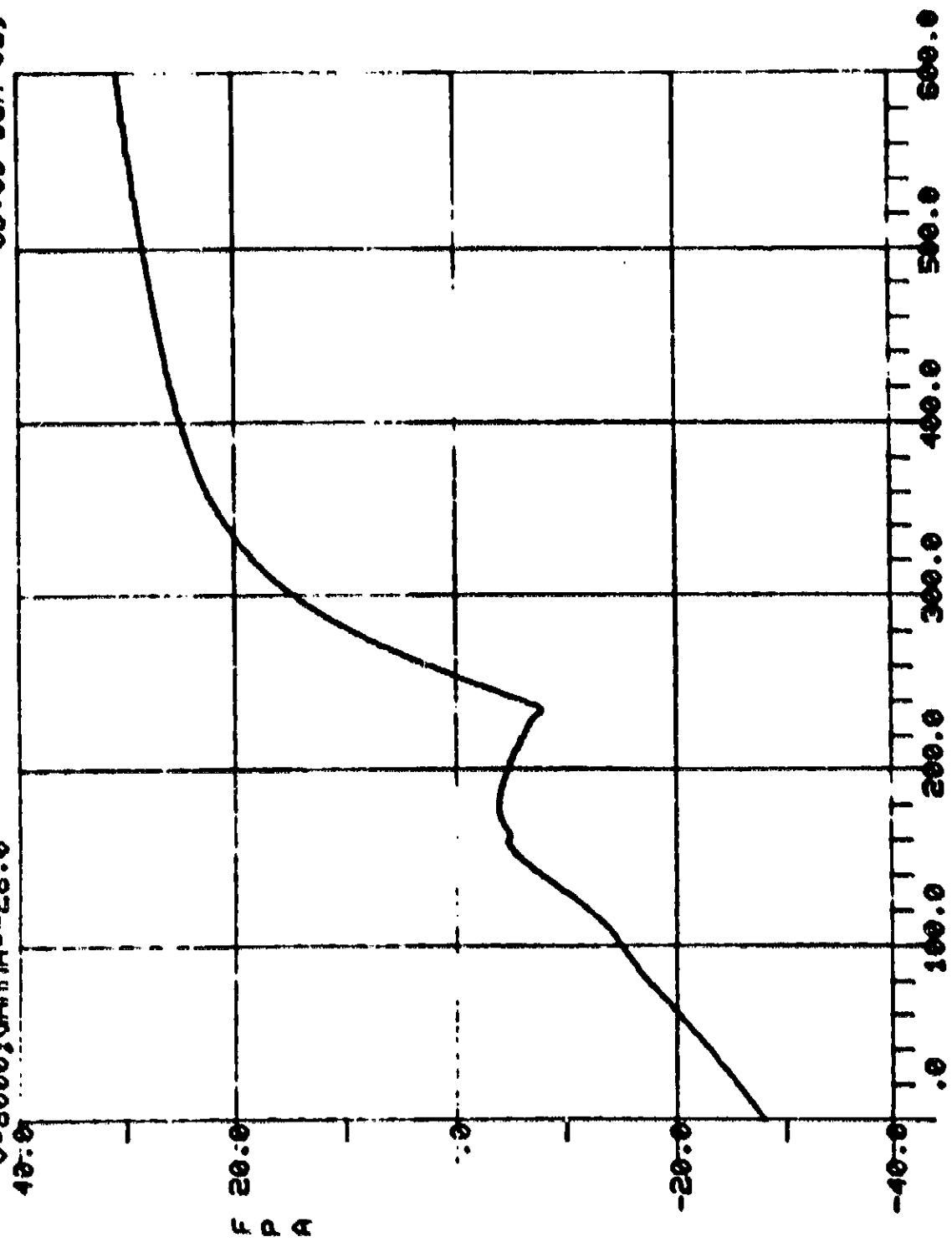


FIGURE 1-28

09:05 JUN 06, '80

U-2000; GAMMA--28.0



T

FIGURE A-20

09:05 JUN 06,'80

V-3000;GAMA-28.0

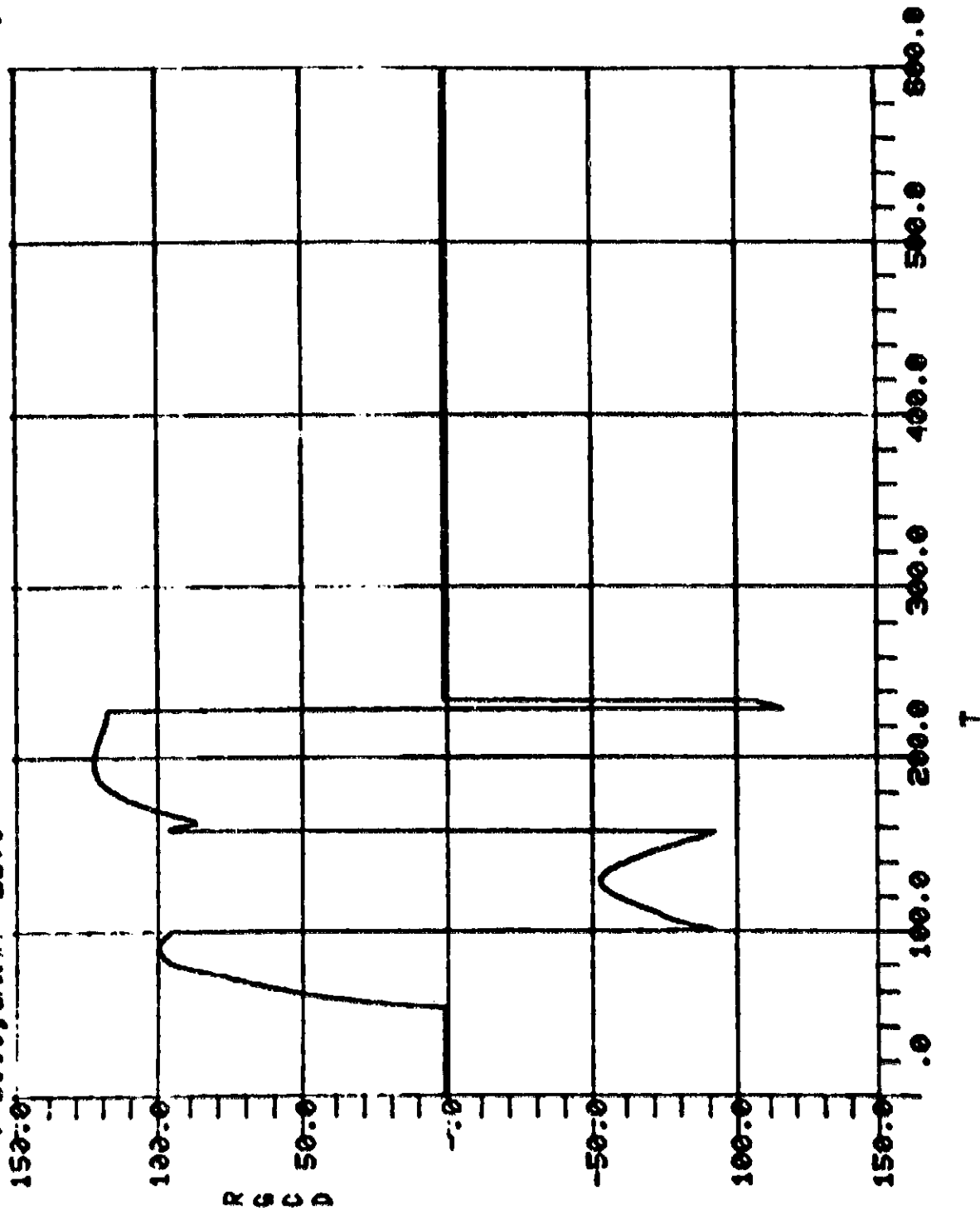
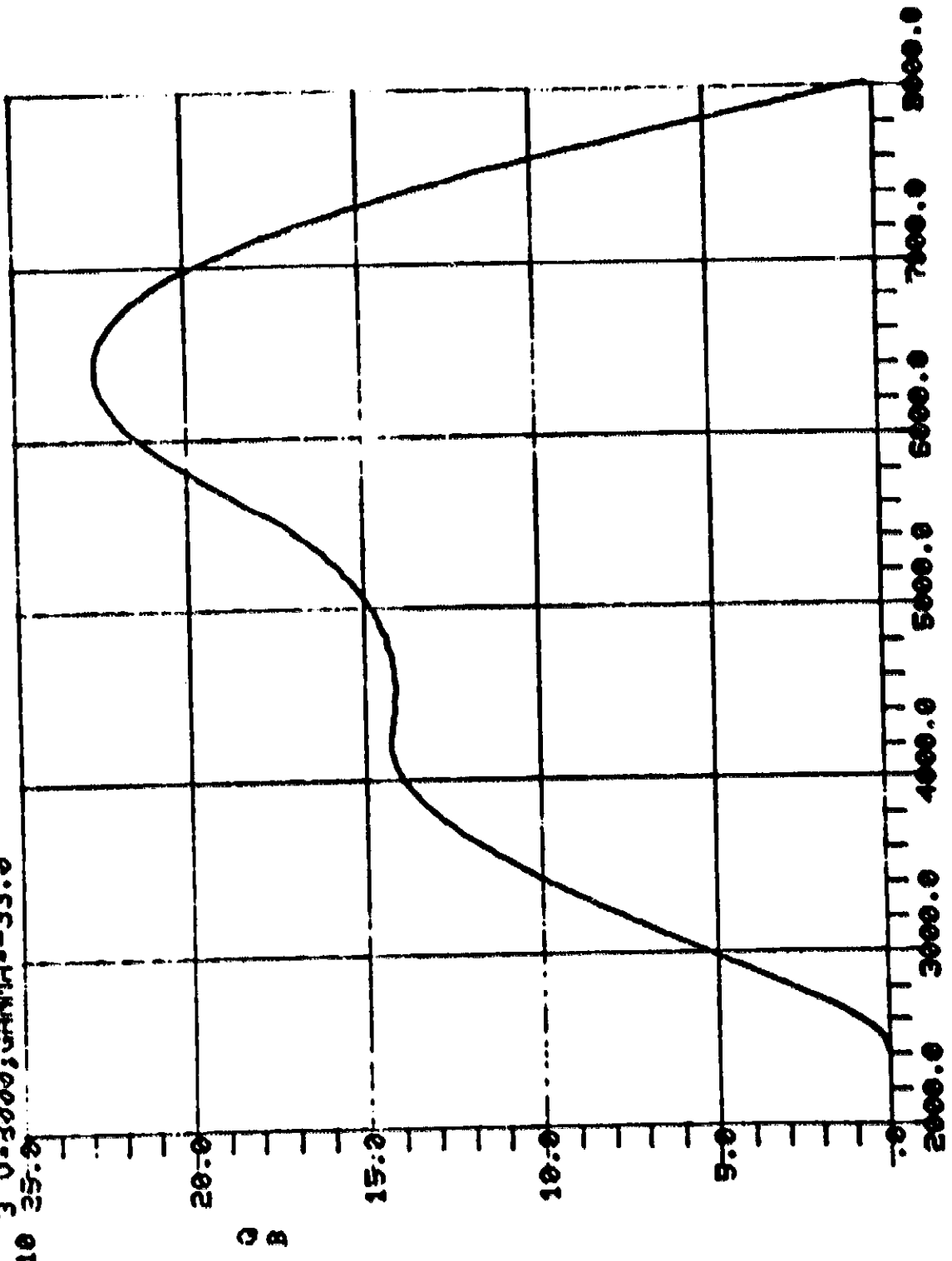


FIGURE 1-10

09:44 JUN 06, '80

3 U-3000; GAMMA=-33.0
10 25.0

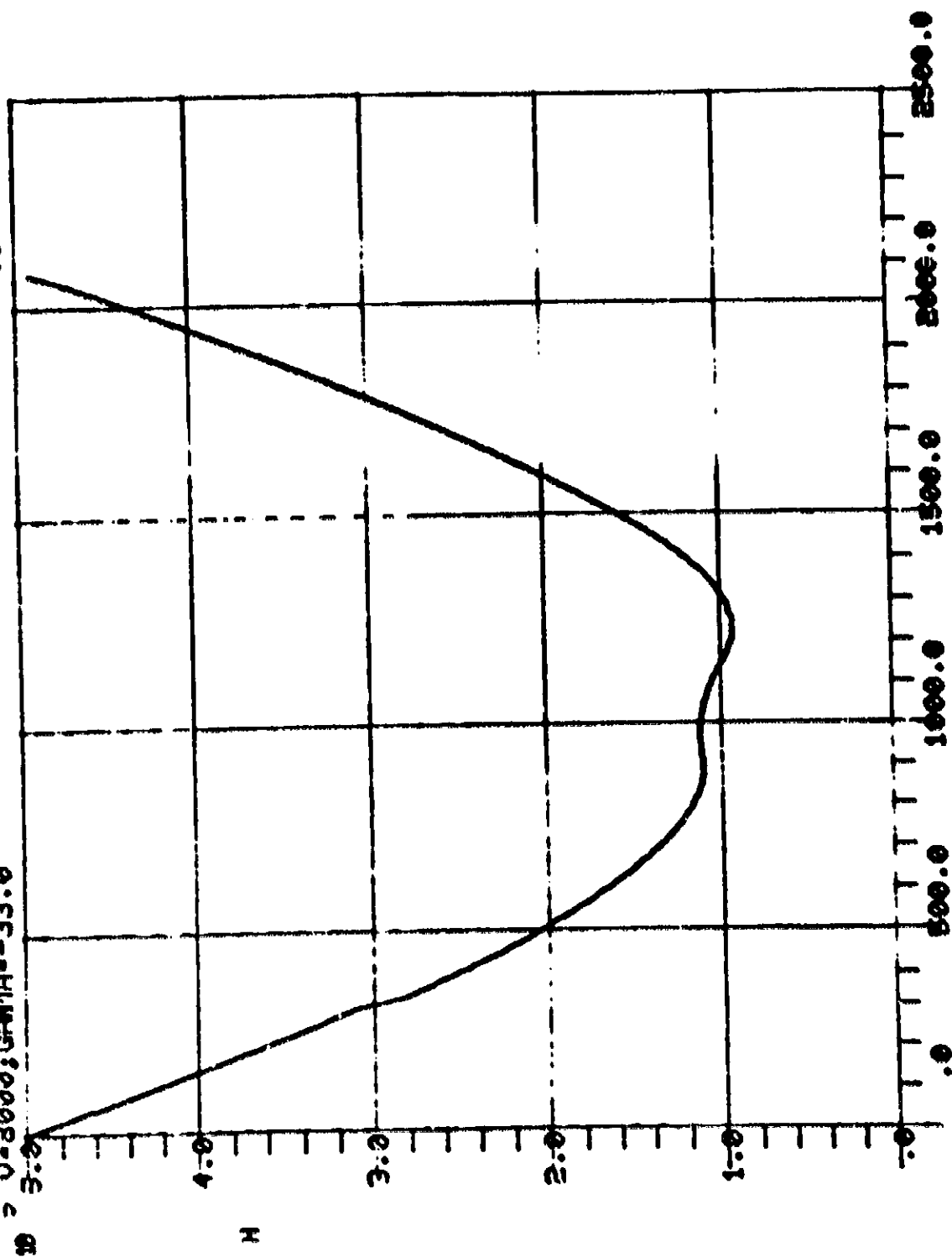


UA

FIGURE A-31

09:44 JUN 06,'80

$\gamma = 3000$; $\text{GAMA} = -33.0$



DRNG

FIGURE A-32

09:44 JUN 06, '80

10 5 V=3000; GAMMA=-33.0

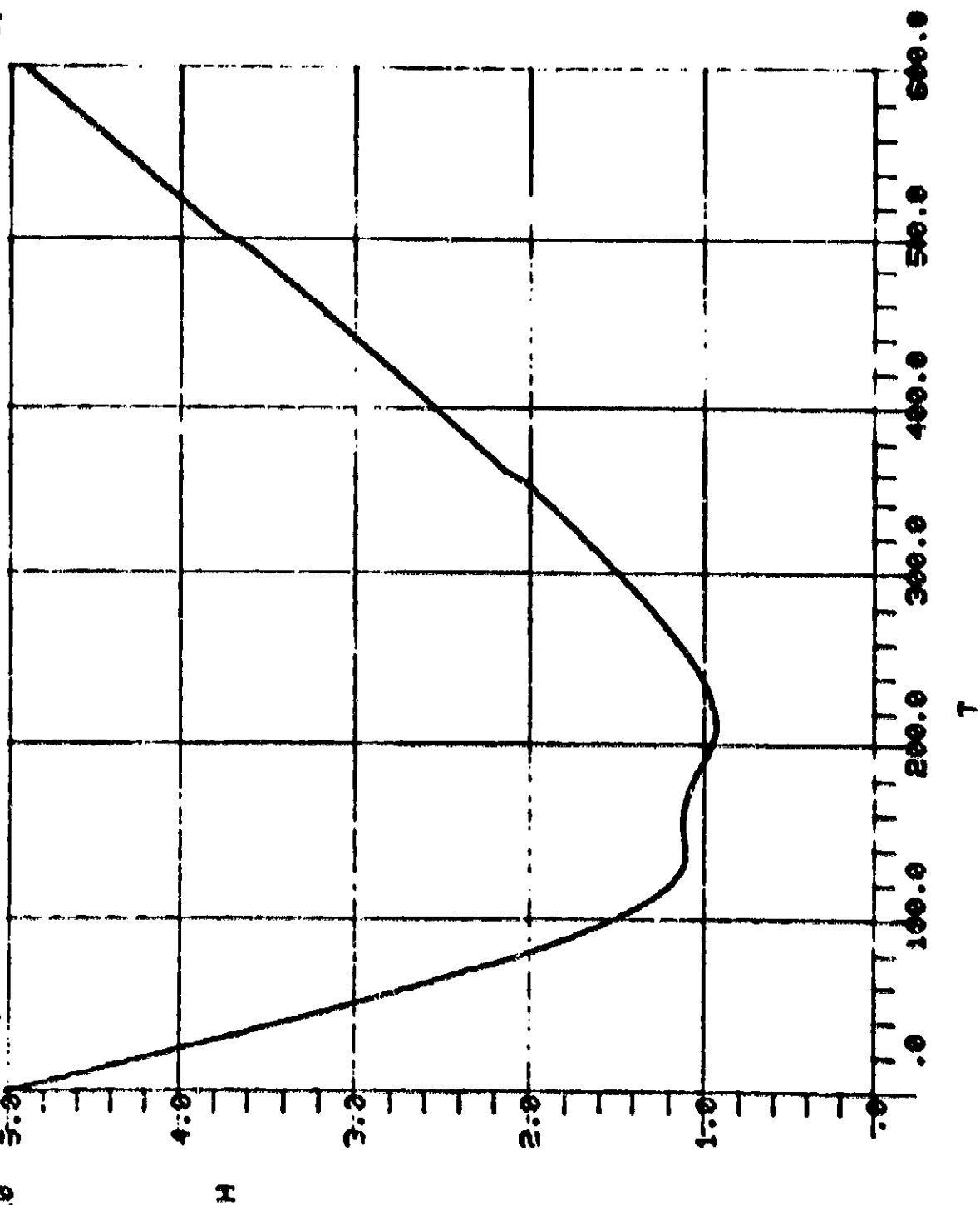
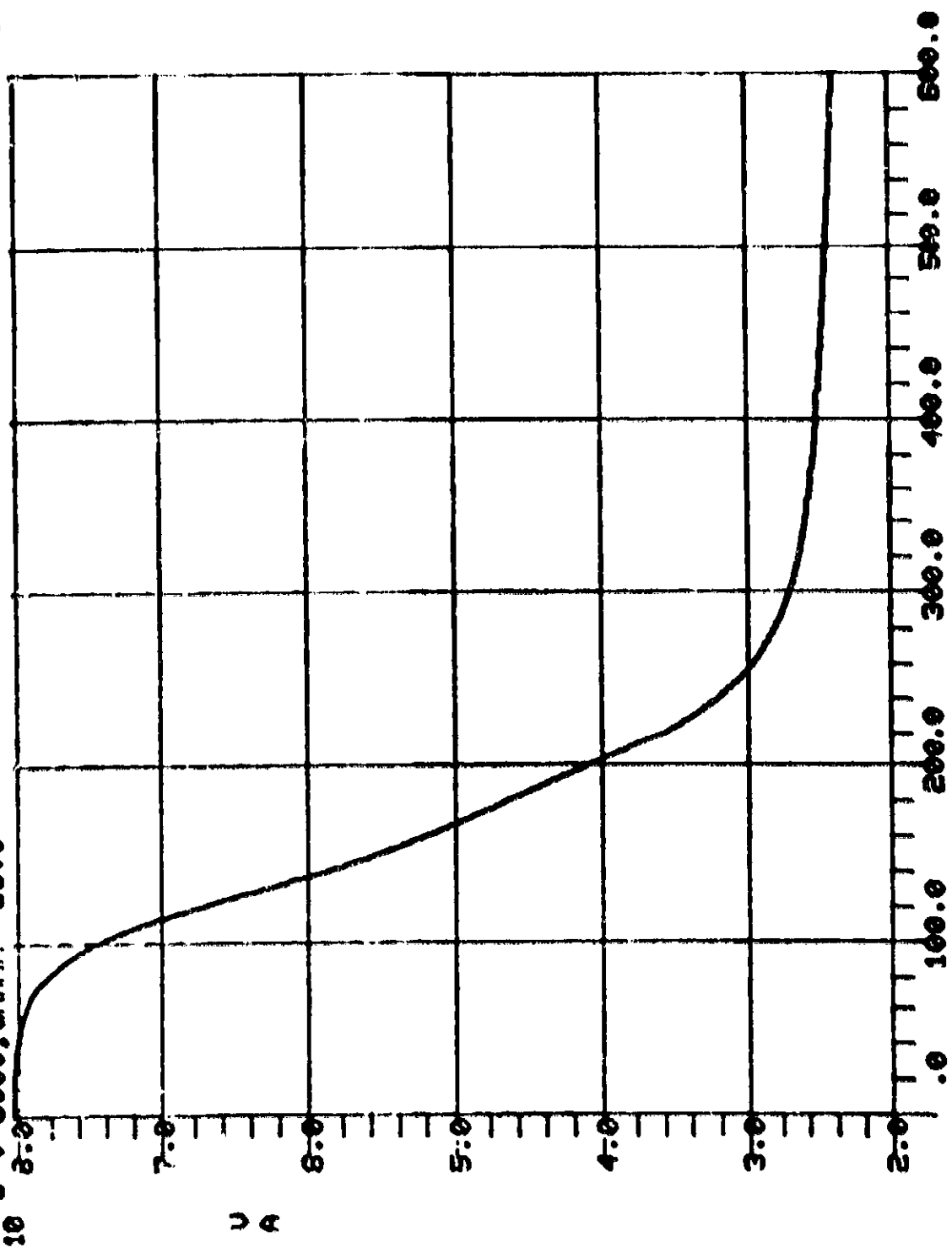


FIGURE A-23

09:44 JUN 06,'80

10 3 U=8000; GAMMA=-33.0



T

FIGURE 1-24

09:44 JUN 06,'80

V=3000; GAMMA=-33.0

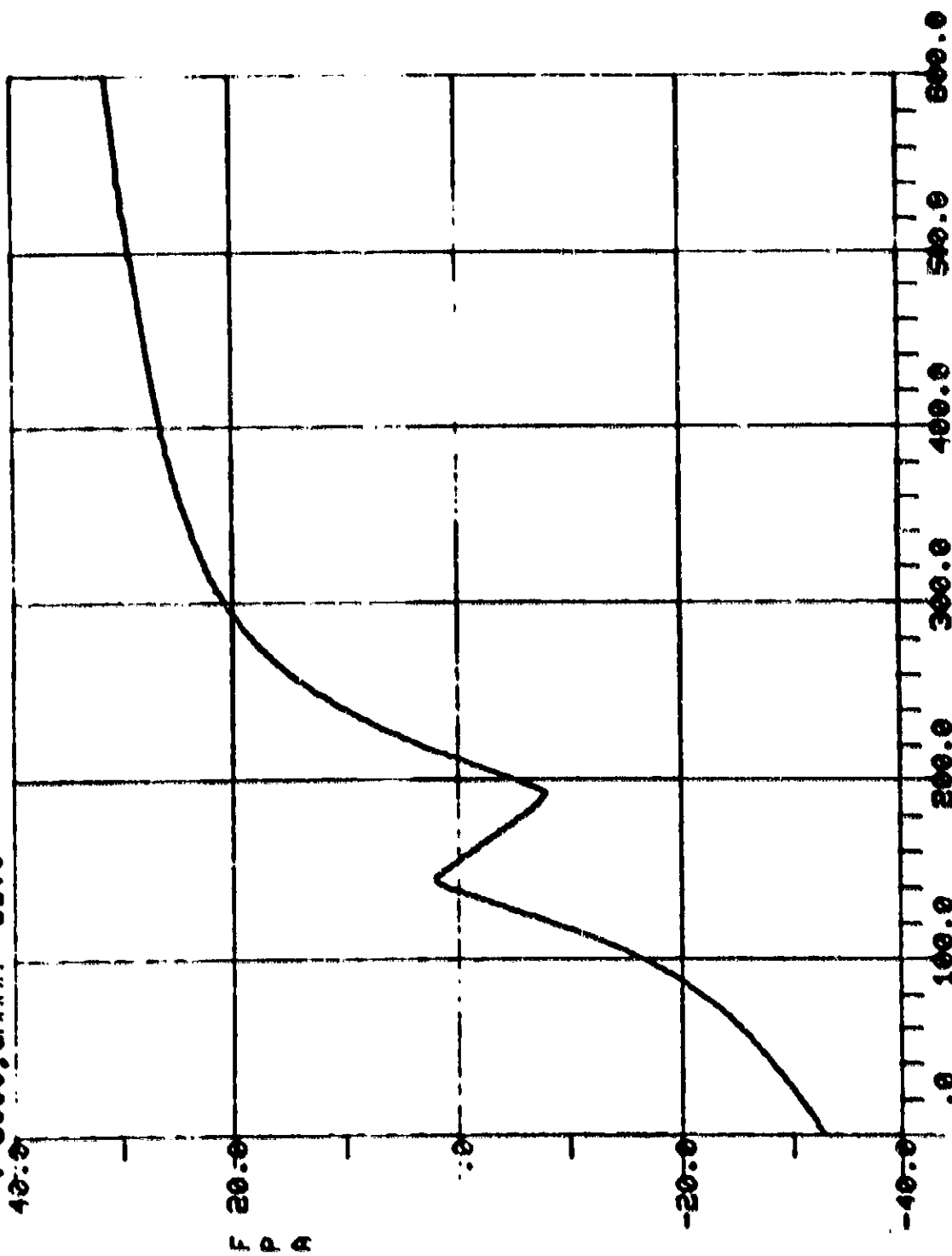


FIGURE A-33

09:44 JUN 06, '80

V=2000; GAMMA=-33.0

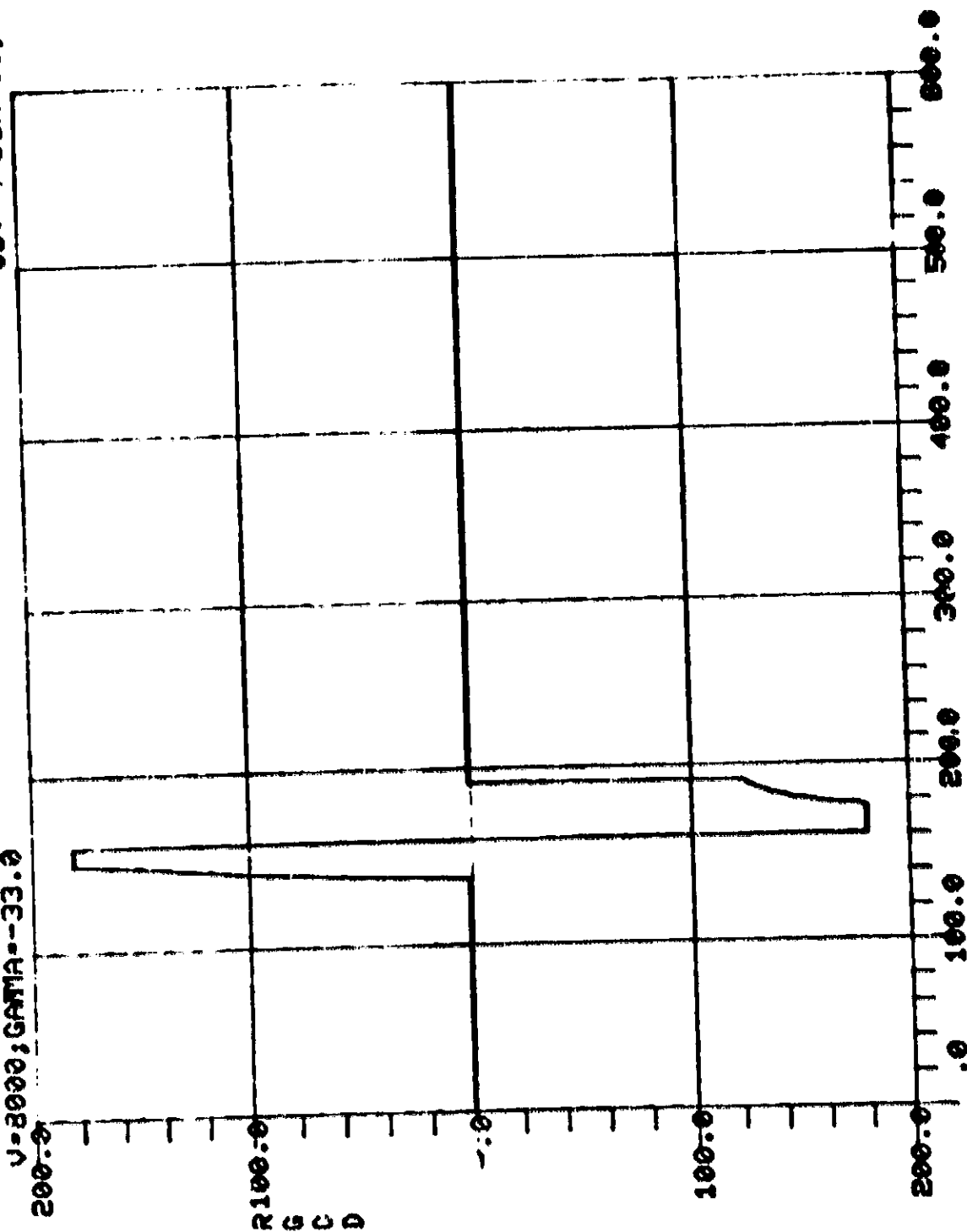


PLATE 1-1

08:22 JUN 05, '80

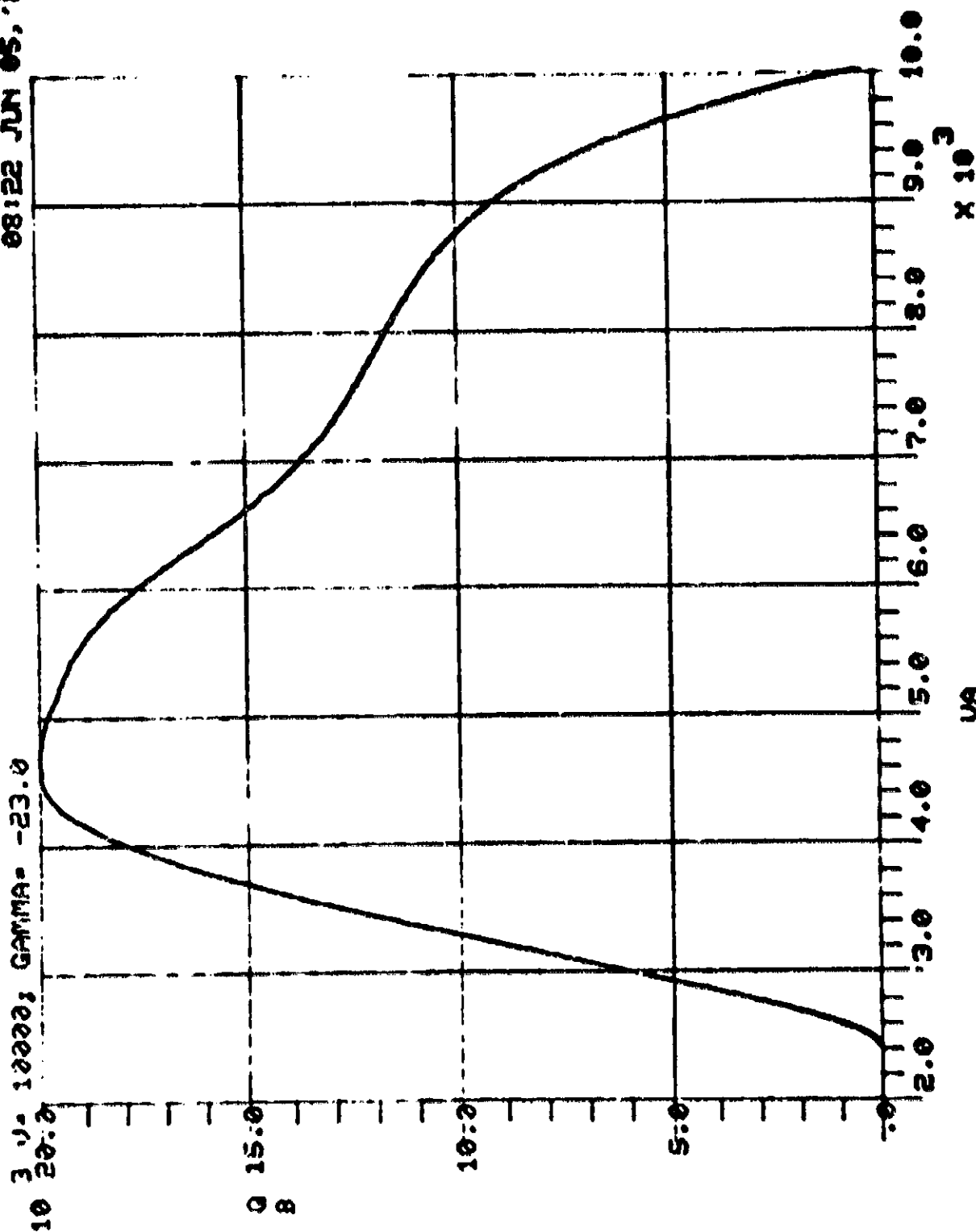
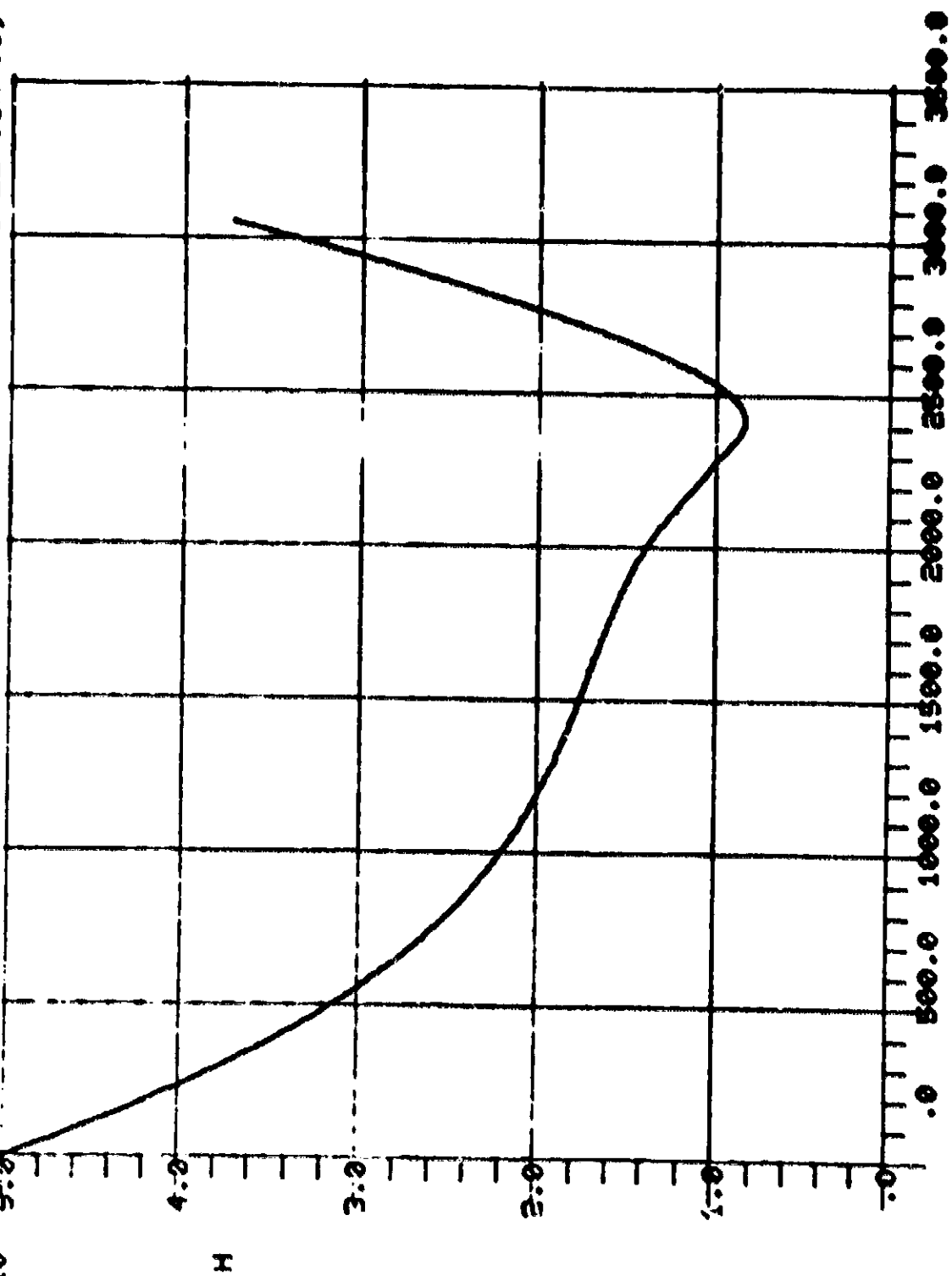


FIGURE A-27

08:22 JUN 05, '80

10 5 V. 10000; GAMMA = -23.0



DRNG

FIGURE A-30

08:22 JUN 05, '80

10 5 U- 10000; GAMMA= -23.0

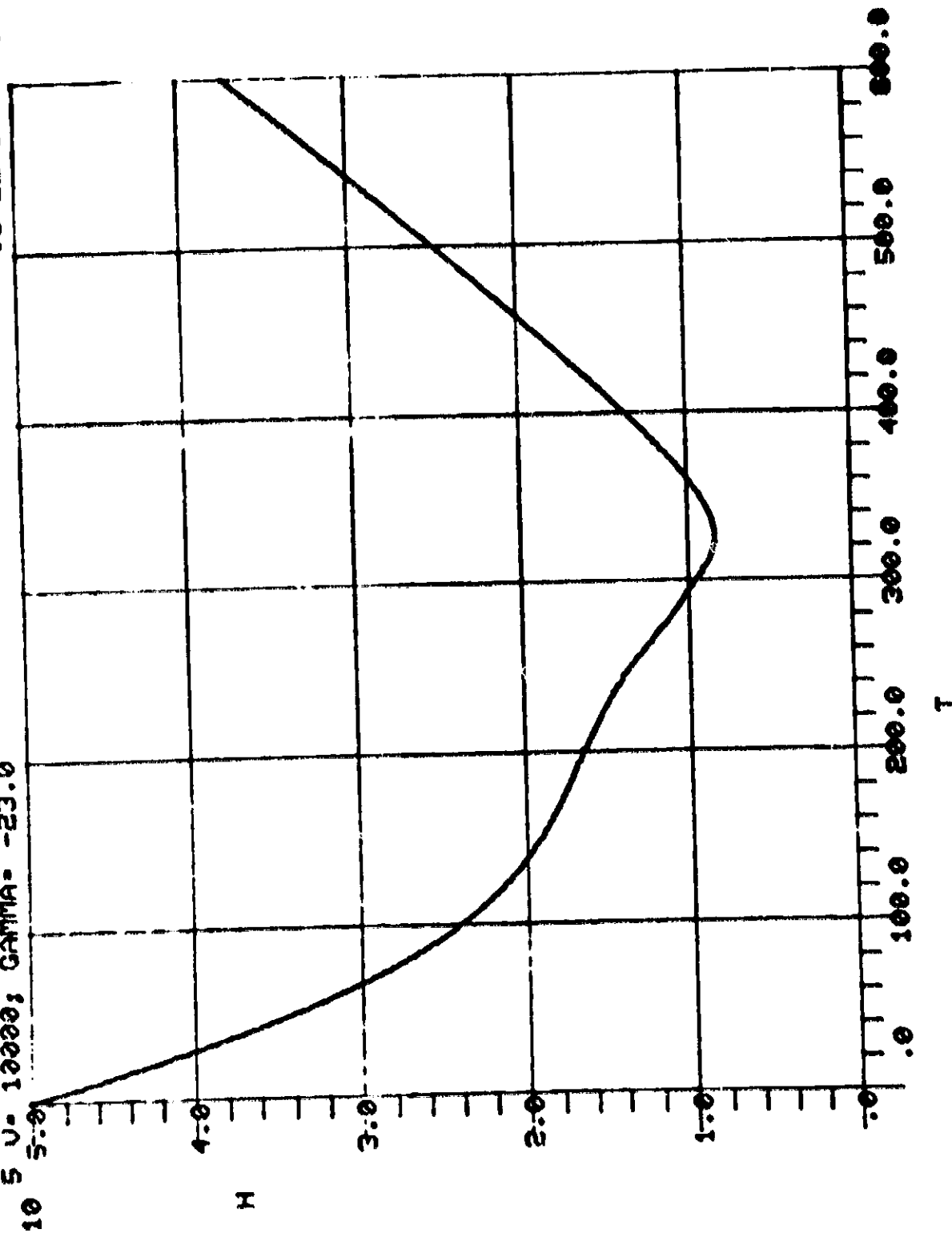


FIGURE A-30

08:22 JUN 05, '80

10 3 U- 10000; GAMMA- -23.0

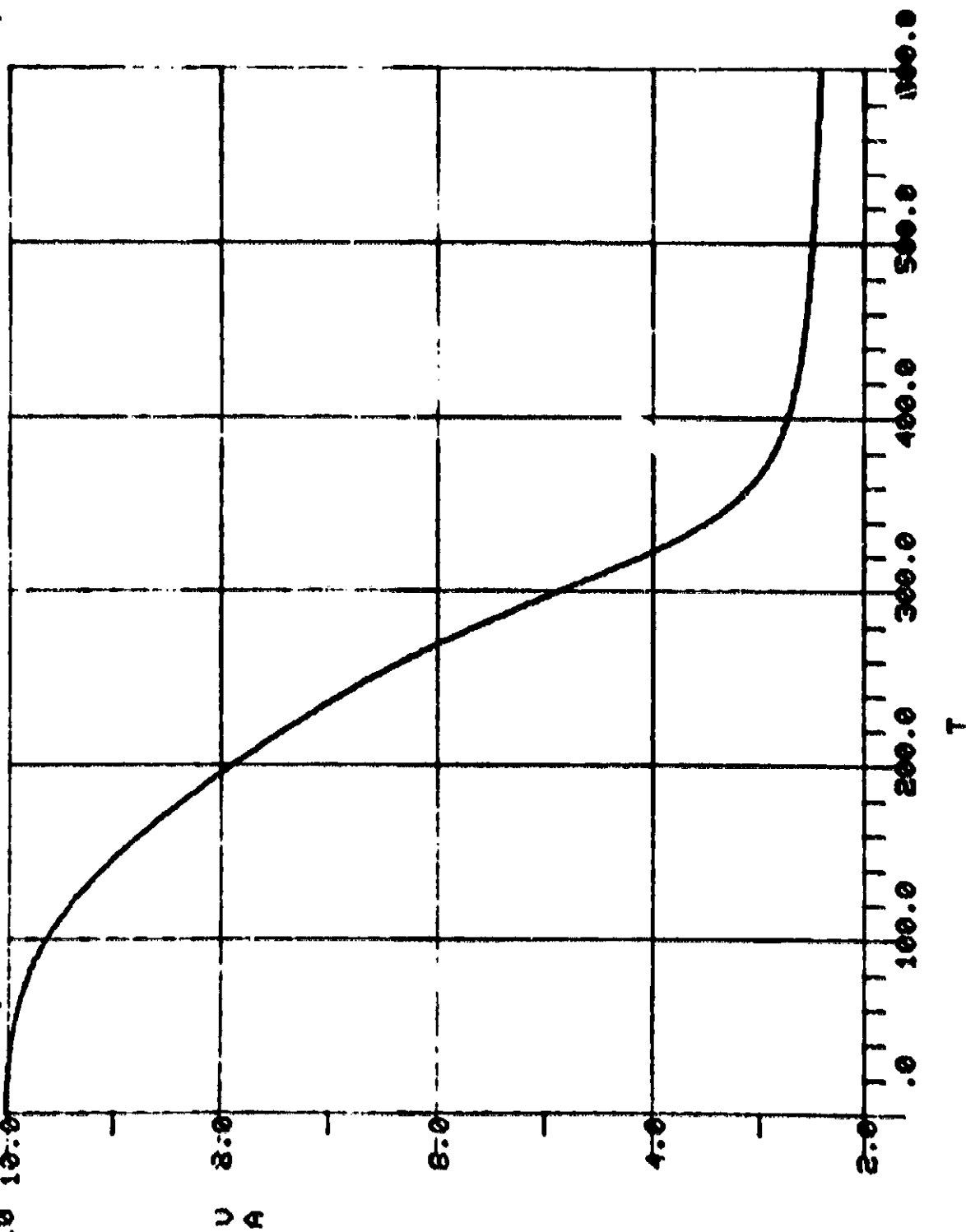
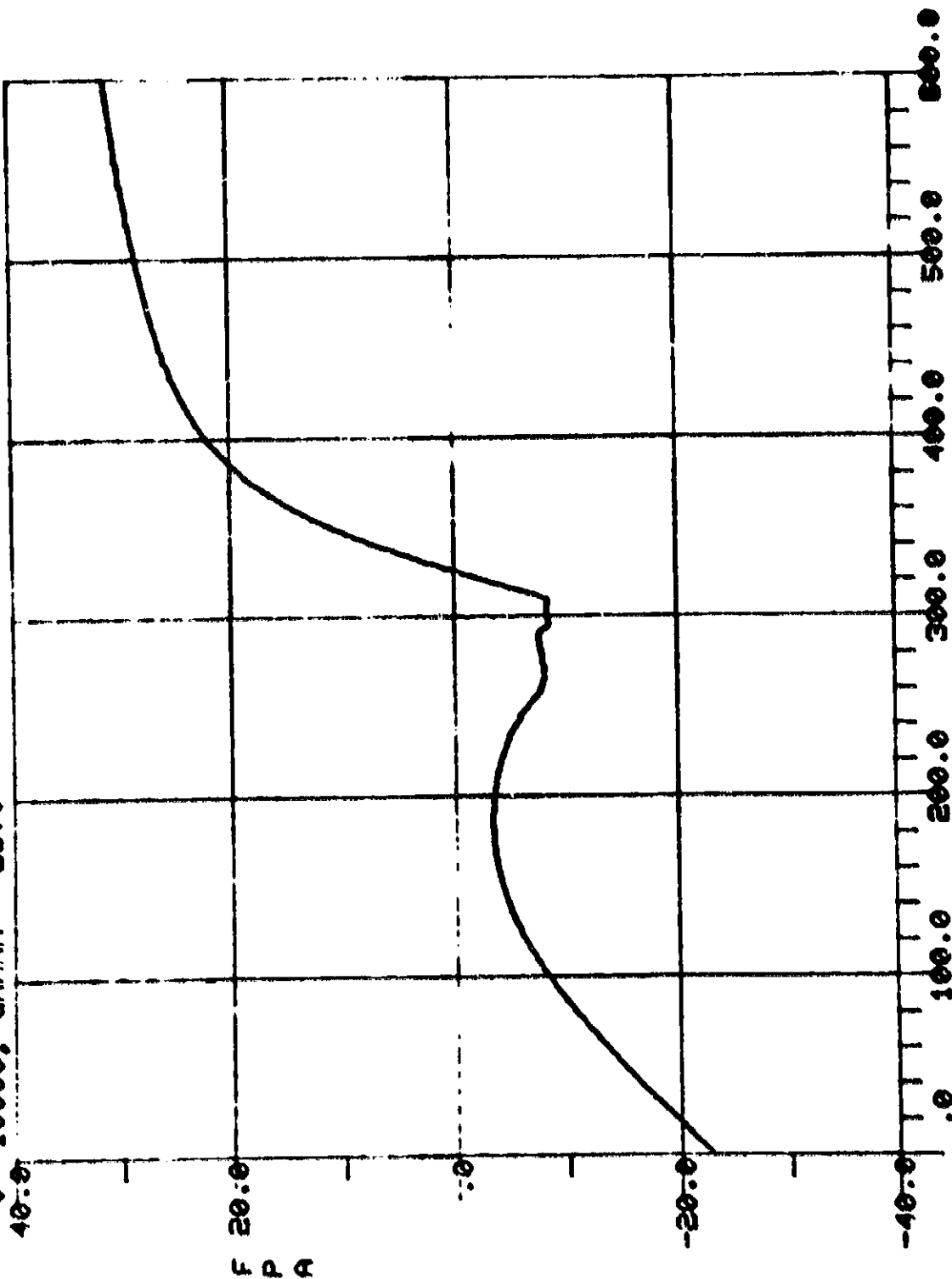


FIGURE A-40

03:22 JUN 05, '80

U- 12000; GAMMA- -23.0

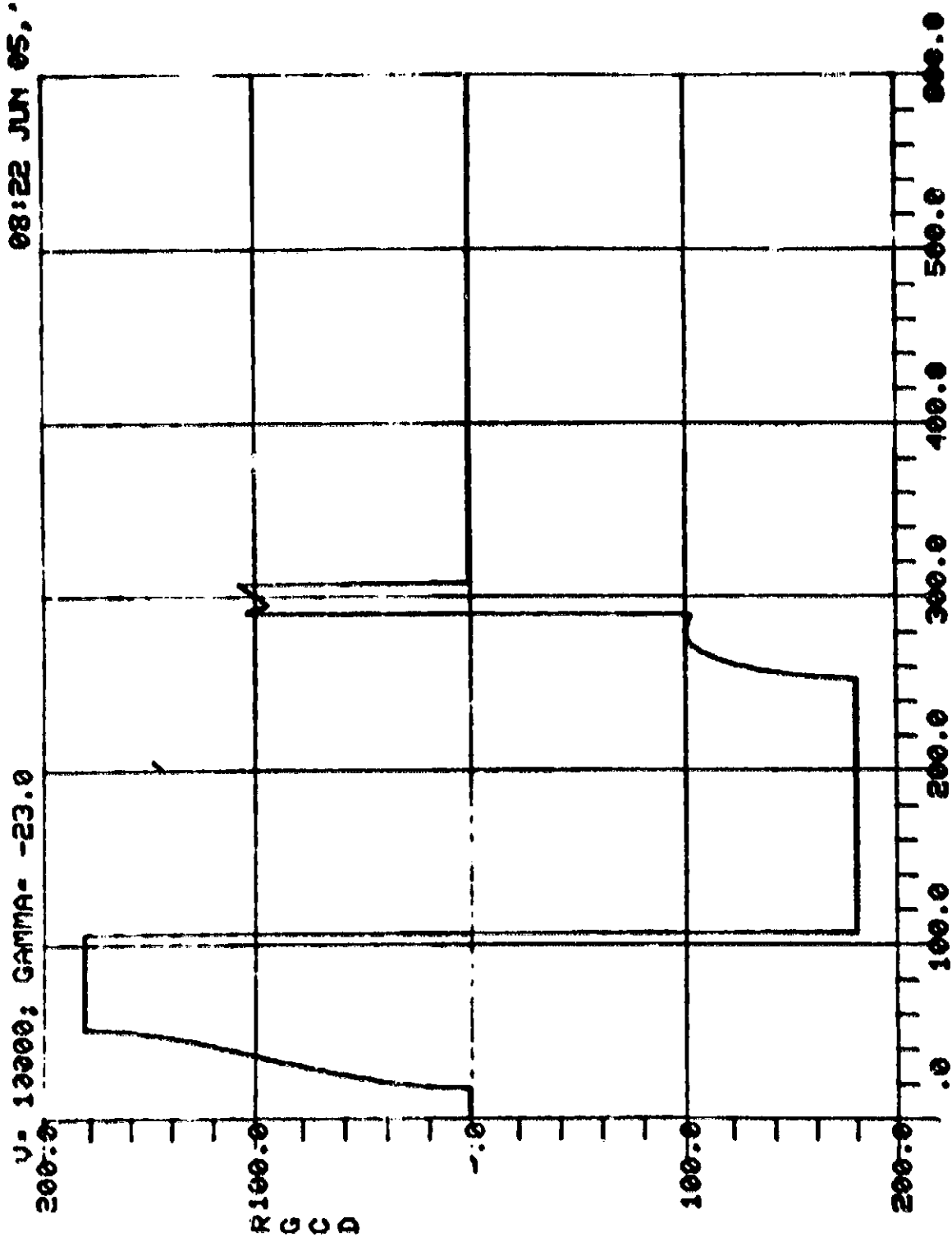


T

FIGURE 1-41

08:22 JUN 85, '80

V= 12000; GAMMA= -23.0



T

FIGURE A-42

16:07 JUN 04, '89

3 U: 1000; GAMMA = -28.0

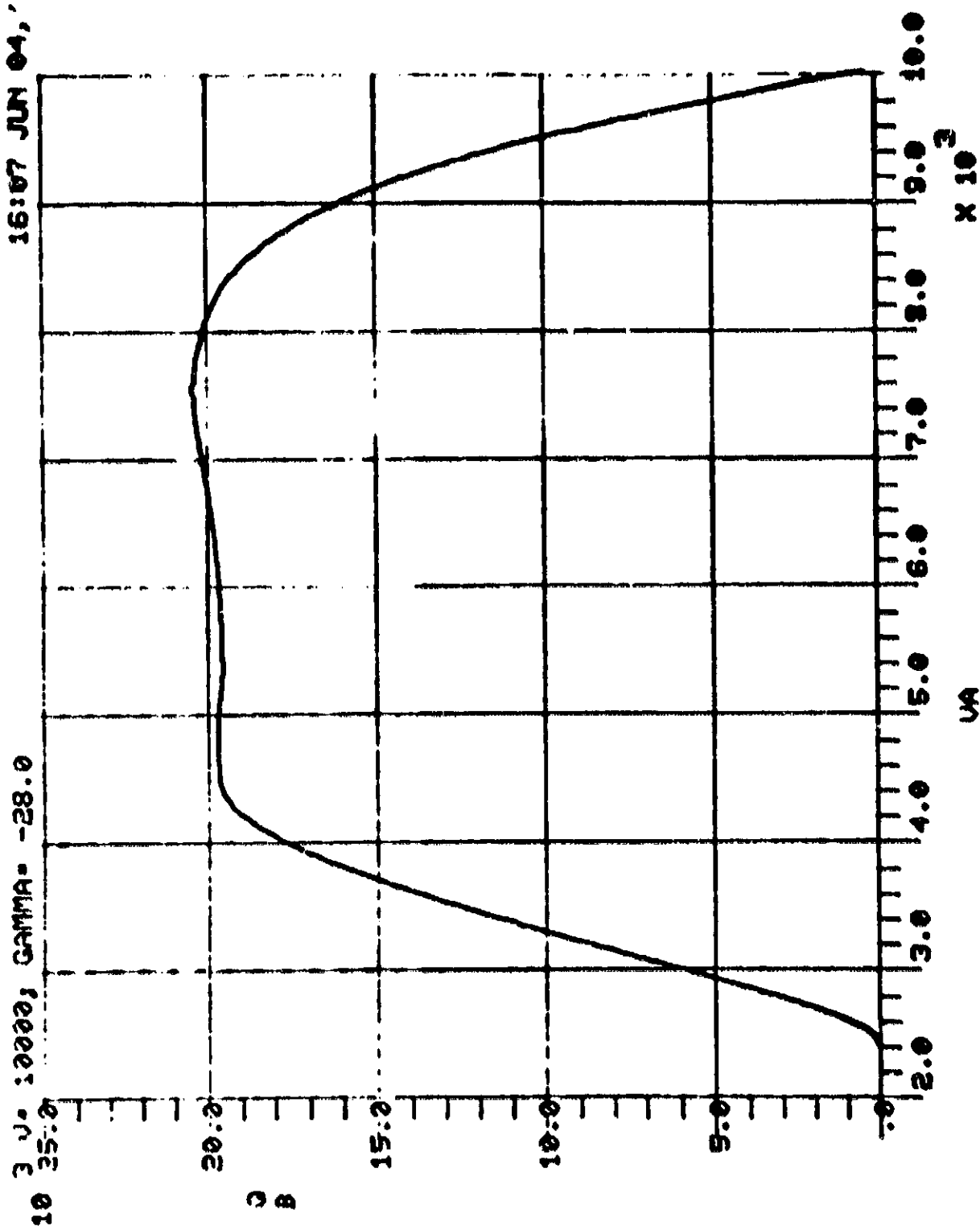
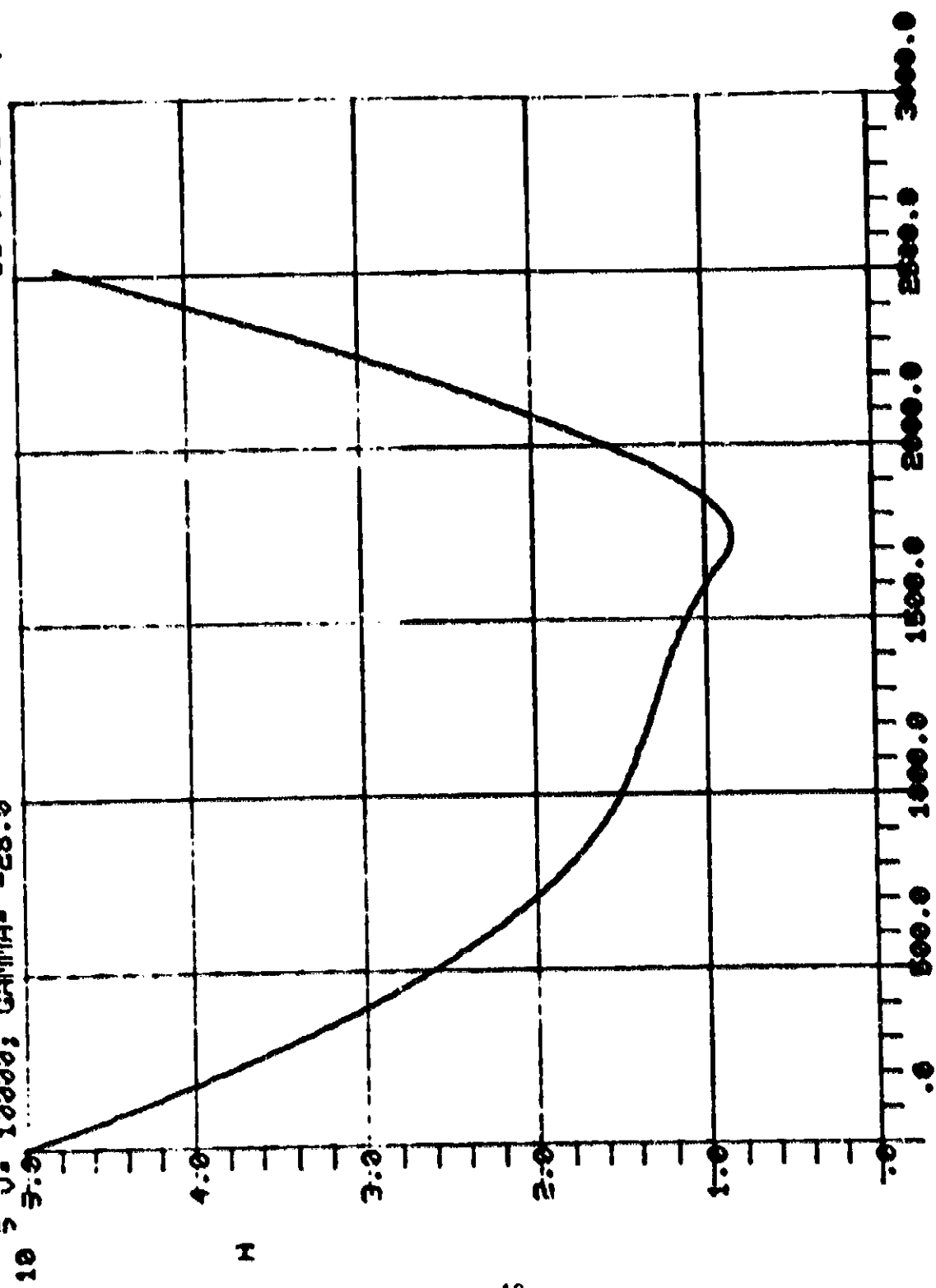


FIGURE A-67

16:07 JUN 04, '80

10 5 V= 12000; GAMMA= -28.0

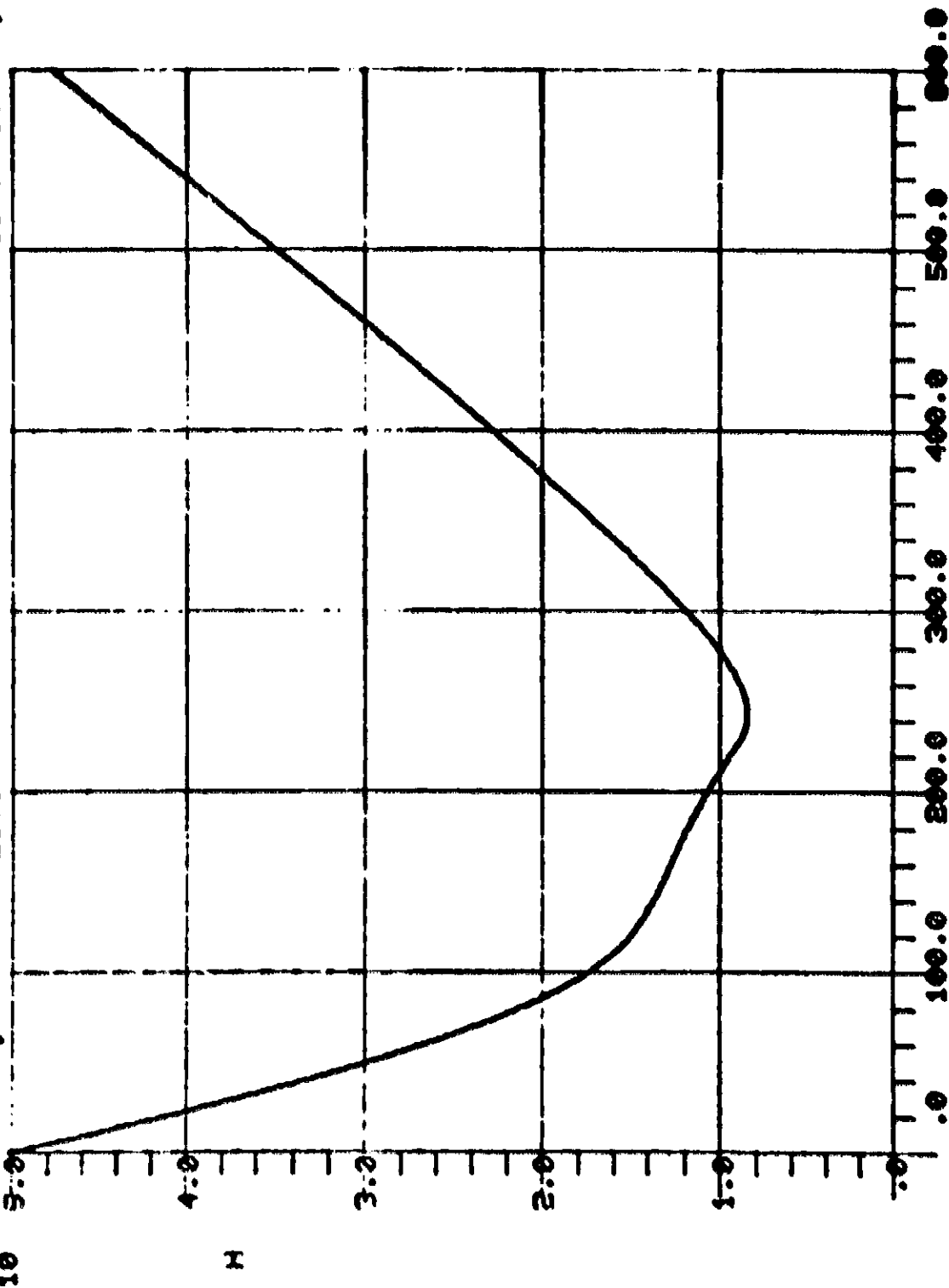


DRNG

FIGURE 1-10

16:07 JUN 04, '80

10 5 V. 10000; GAMMA= -28.0



T

FIGURE A-45

16:07 JUN 04, '80

10 3 V= 12000; GAMMA= -28.0

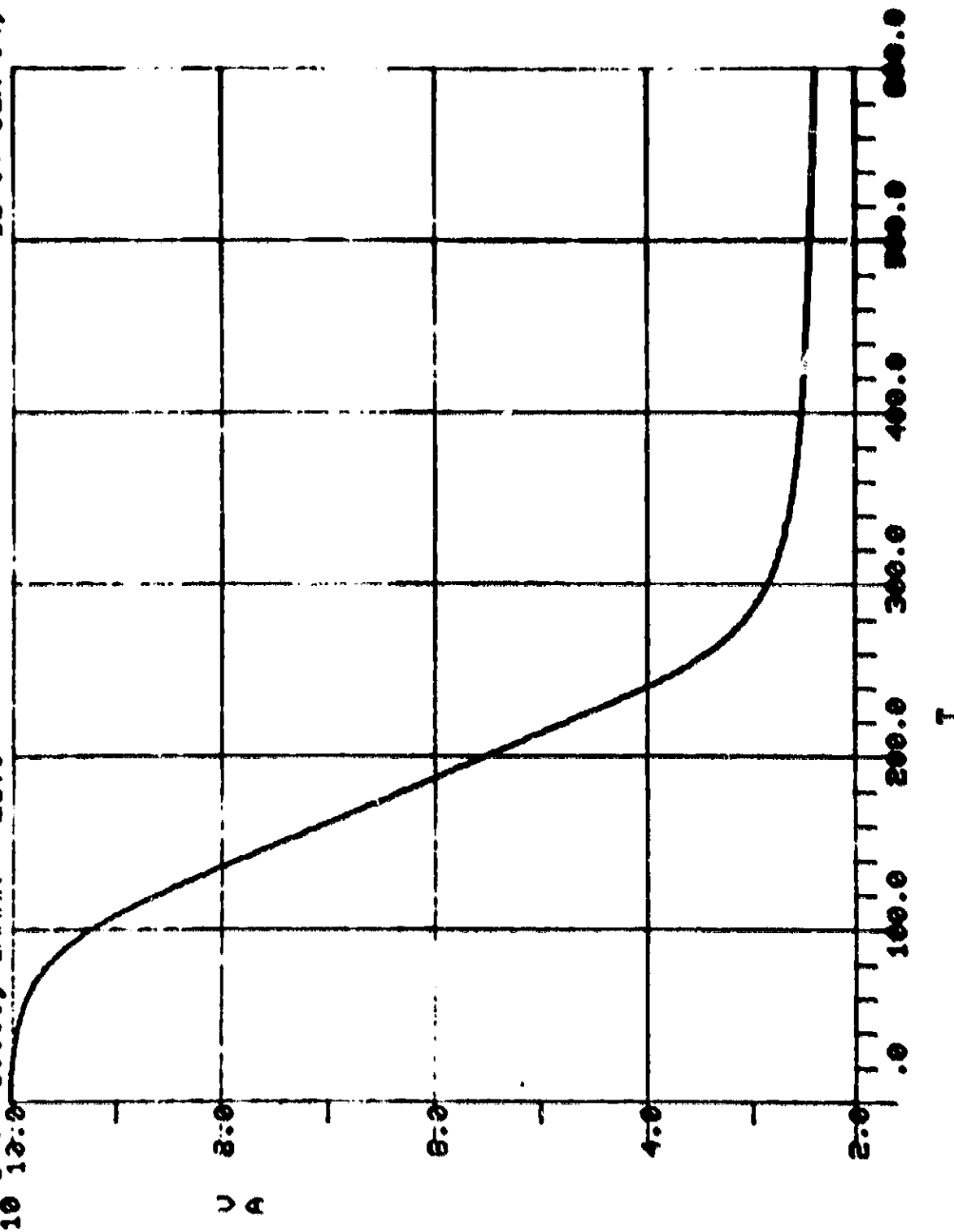


FIGURE 7-15

16:07 JUN 04, '80

V= 10000; GAMMA= -28.0

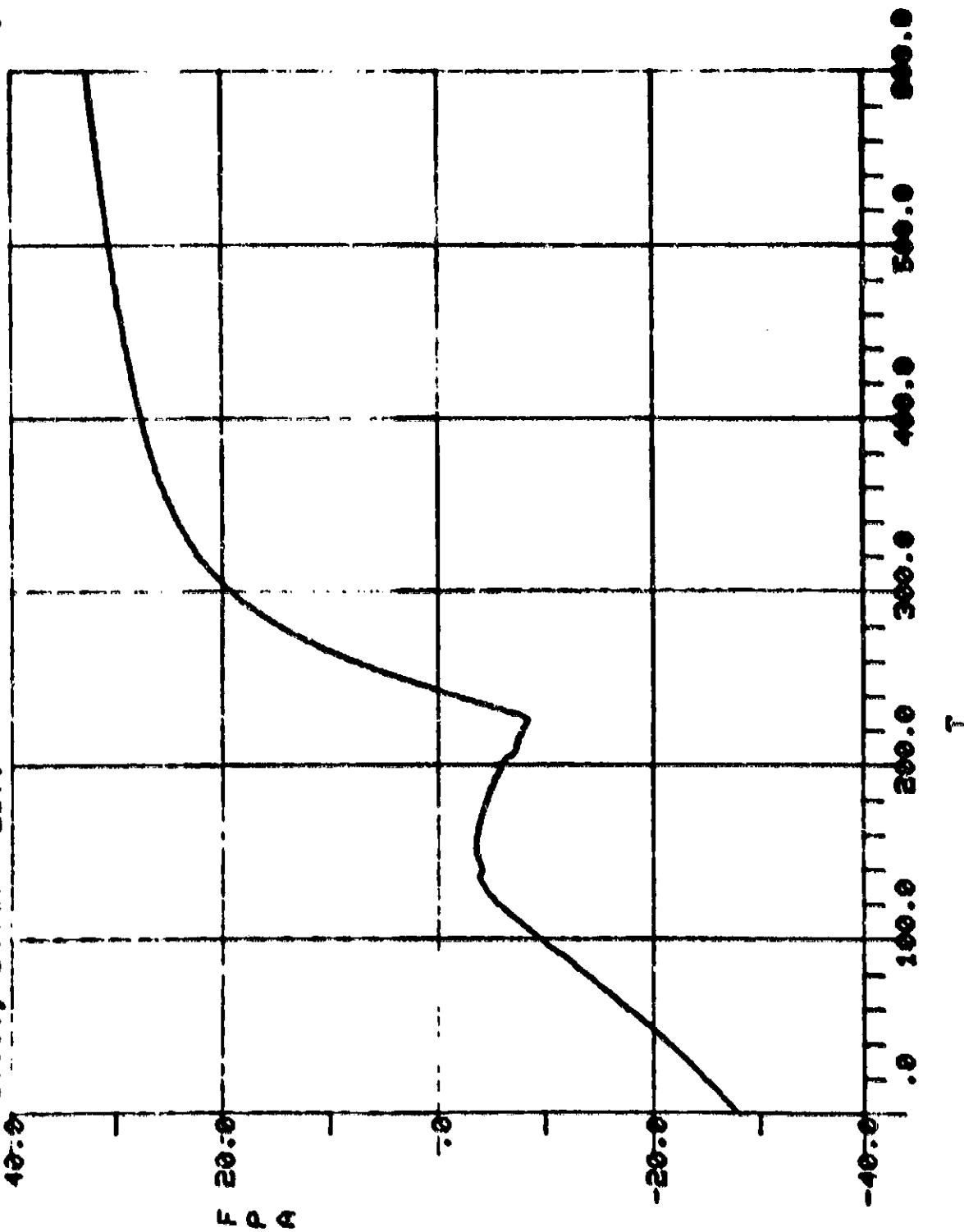
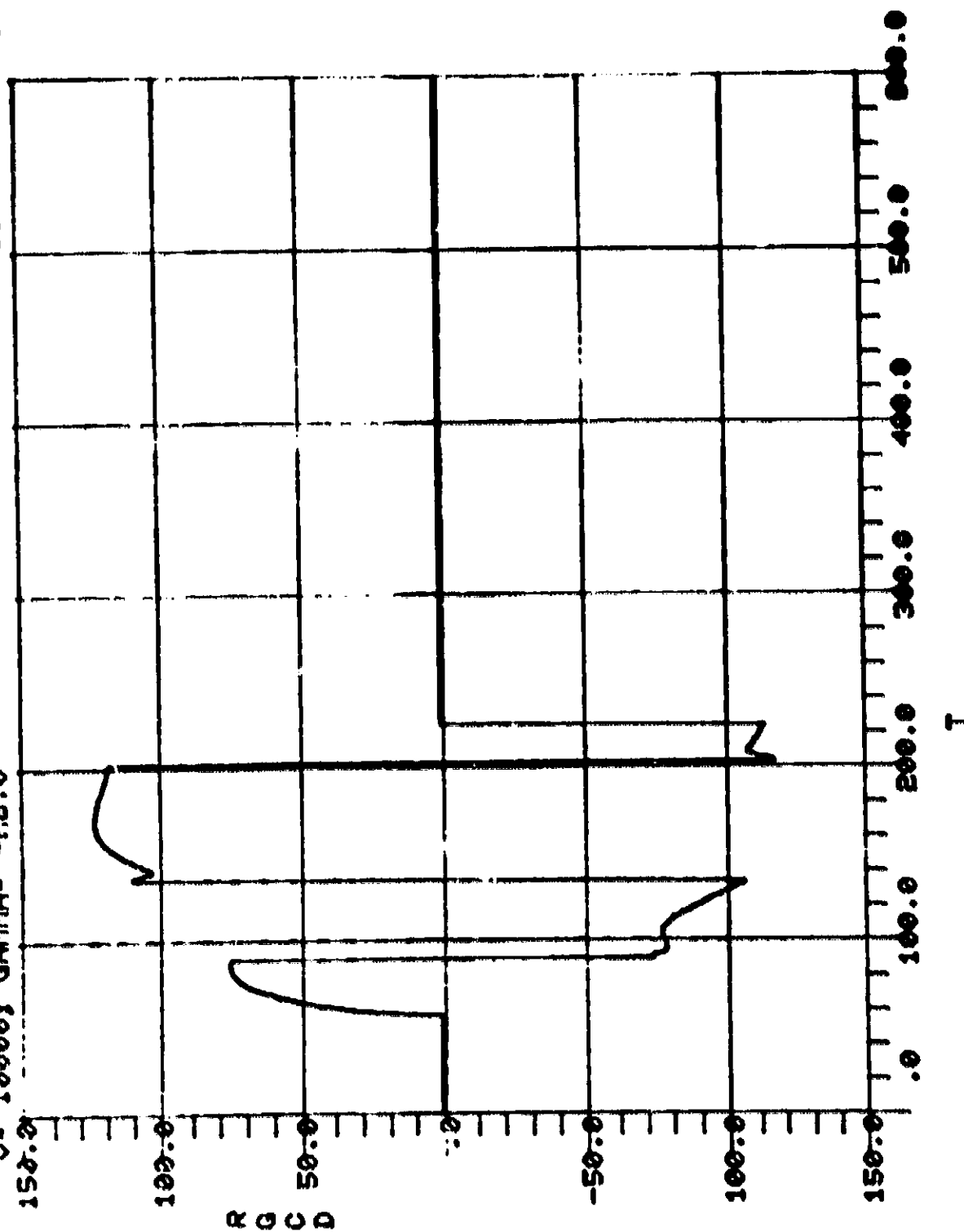


FIGURE 1-15

16:07 JUN 04, '80

U = 10000, GAMMA = -28.0



08:45 JUN 05, '80

3 U. 12000; GAMMA = -32.5
10 40:2

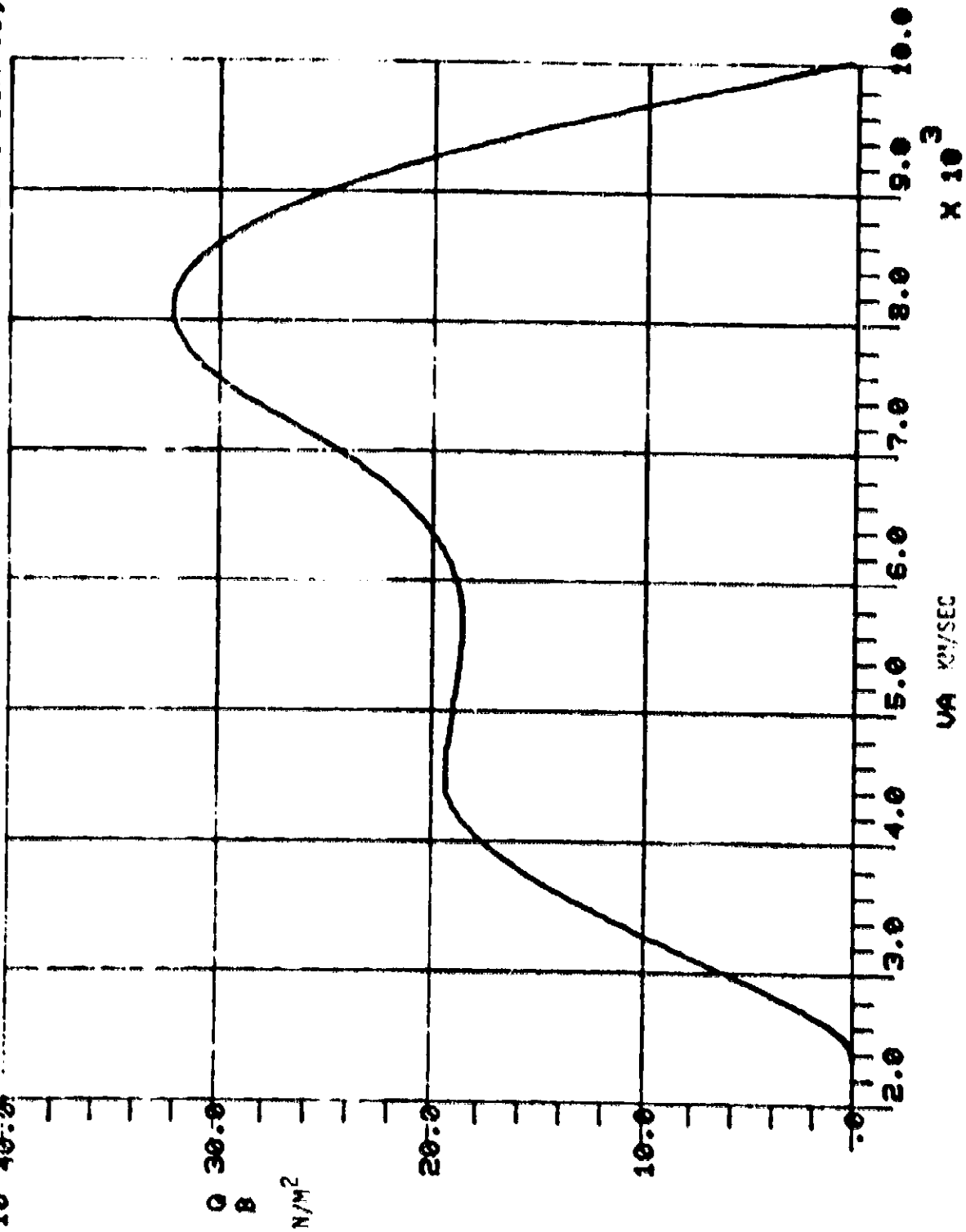
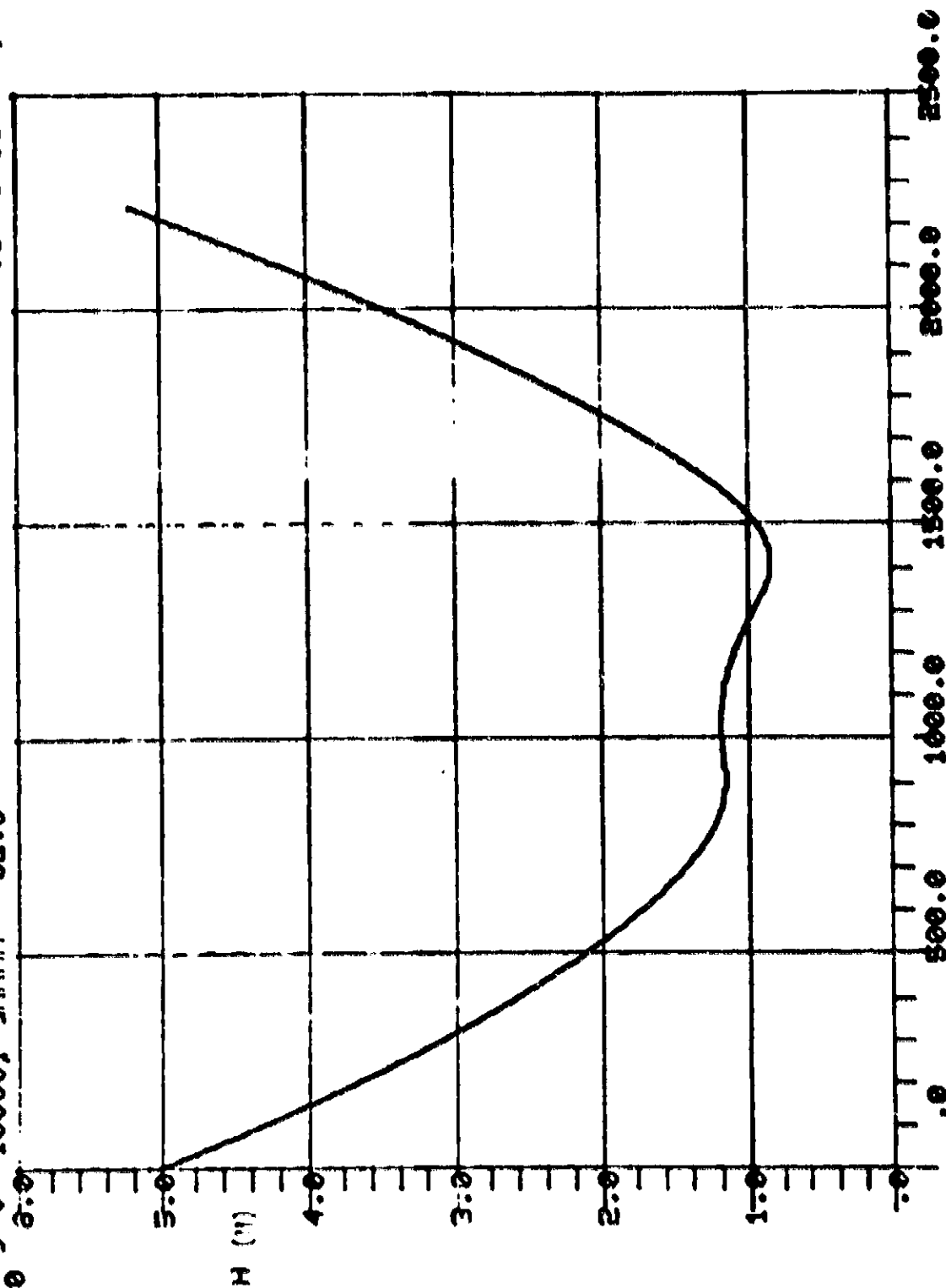


FIGURE A-10

08:45 JUN 05, '80

10 5 U- 10000; GAMMA- -32.5



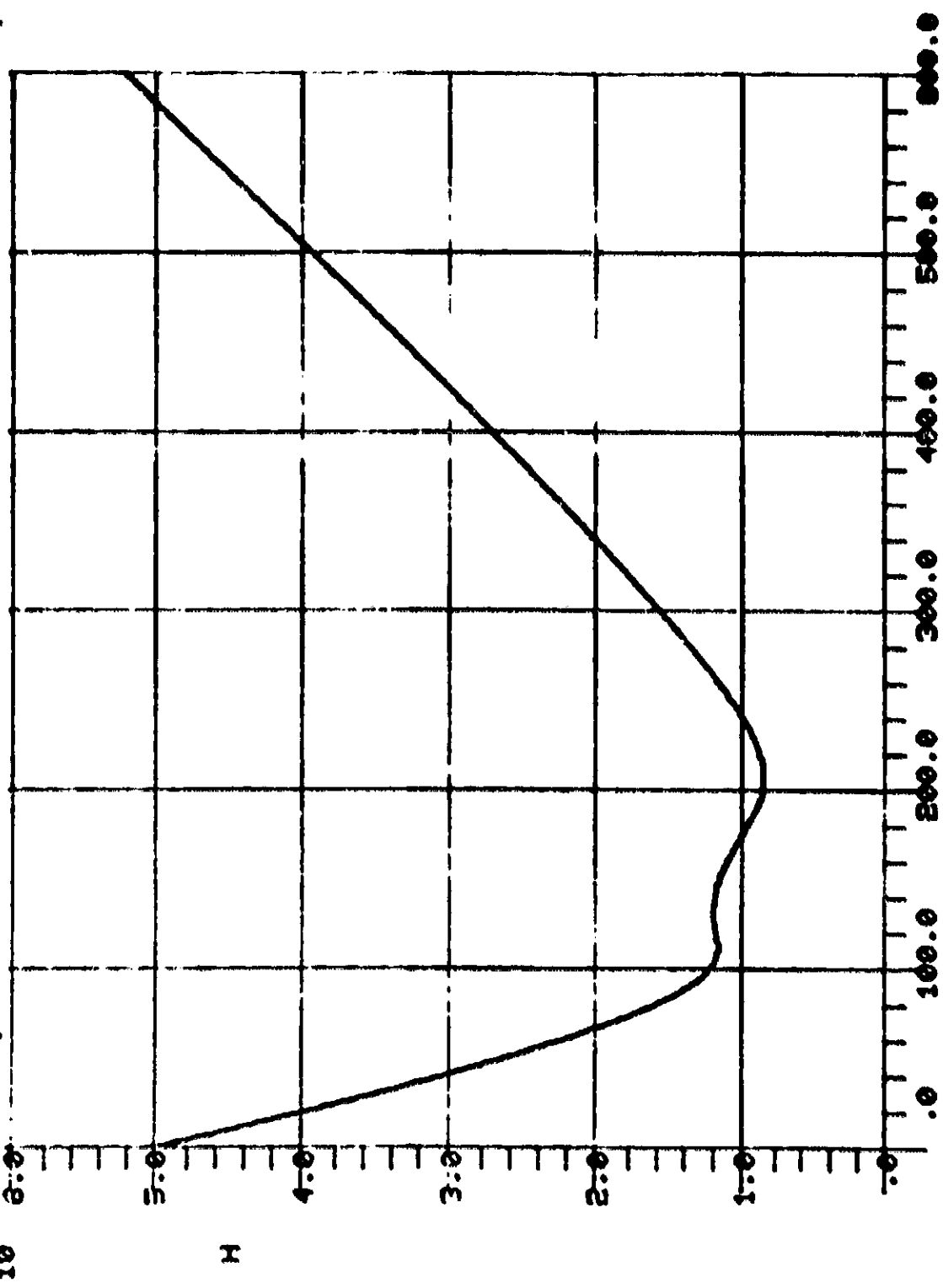
DRNG KI

FIGURE 50
TITAN

FIGURE 51

08:45 JUN 05, '80

10 5 U= 10000; GAMMA= -32.5



T

FIGURE A-52

08:45 JUN 05, '80

3 V- 10000; GAMMA- -32.5

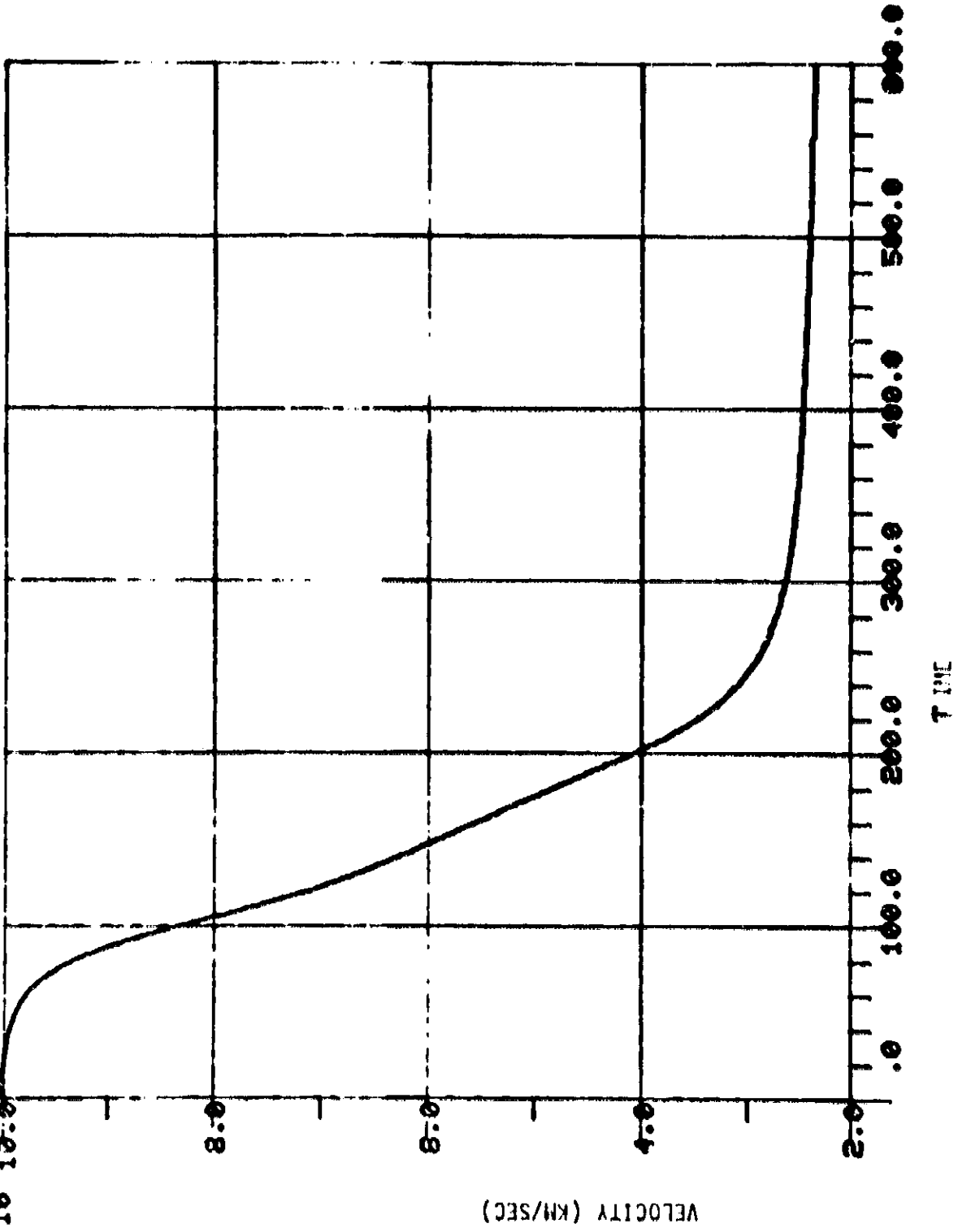


FIGURE 52
TITAN

FIGURE 5-32

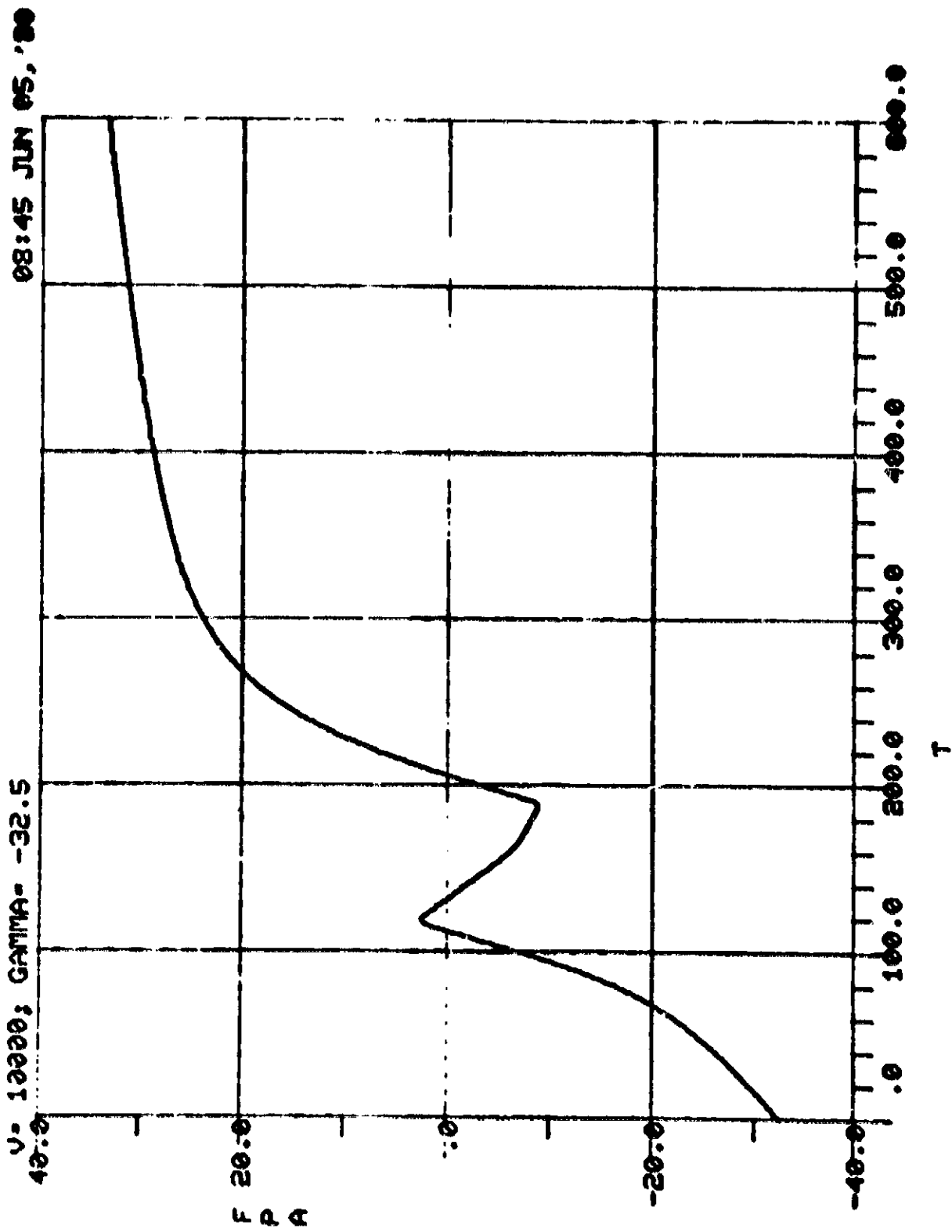
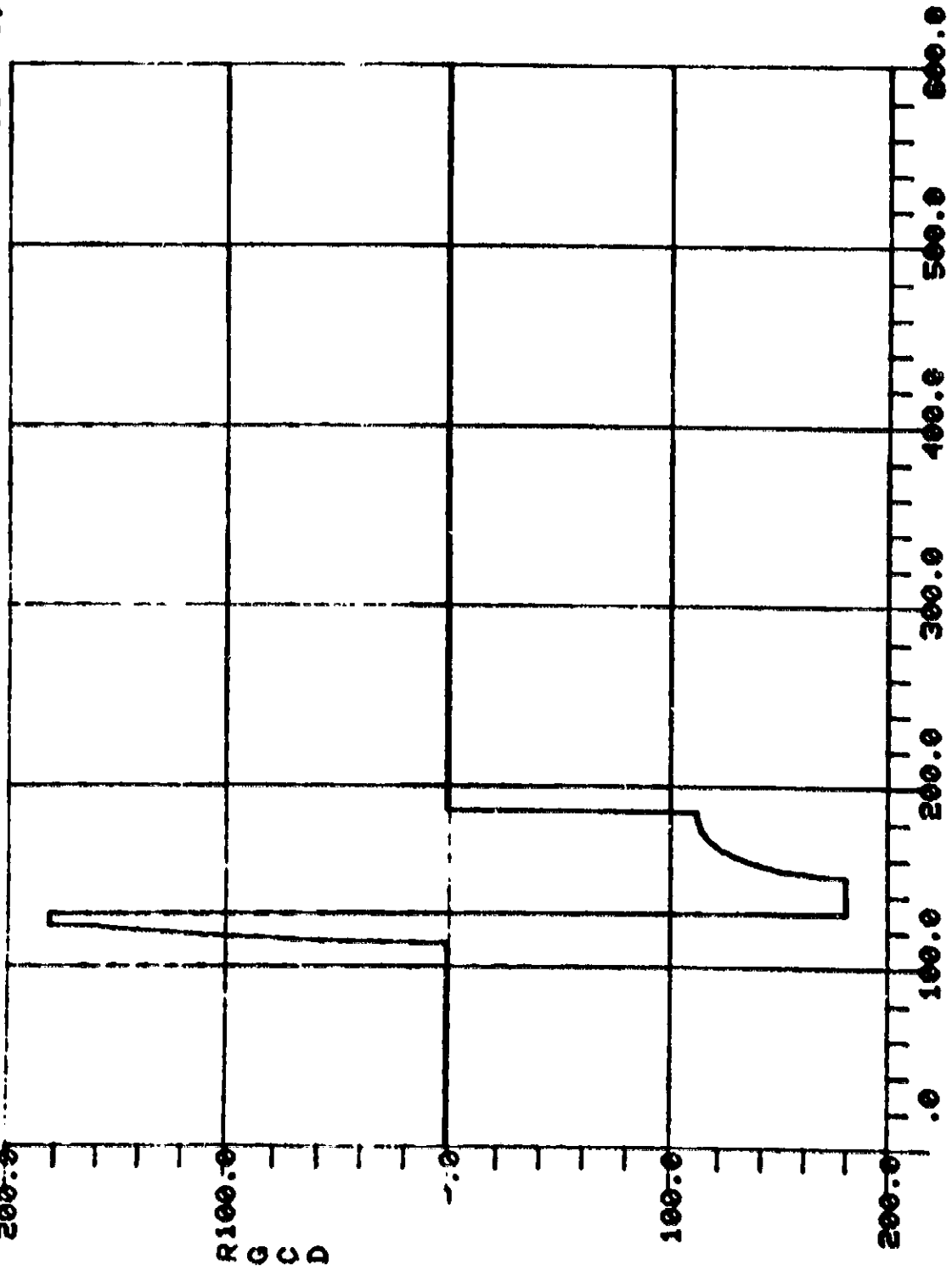


FIGURE A-5

08:45 JUN 05, '80

V= 1000; GAMMA= -32.5



T

FIGURE A-54

09:04 JUN 05, '80

3 V. 12000; GAMMA -33.0
10 40.0

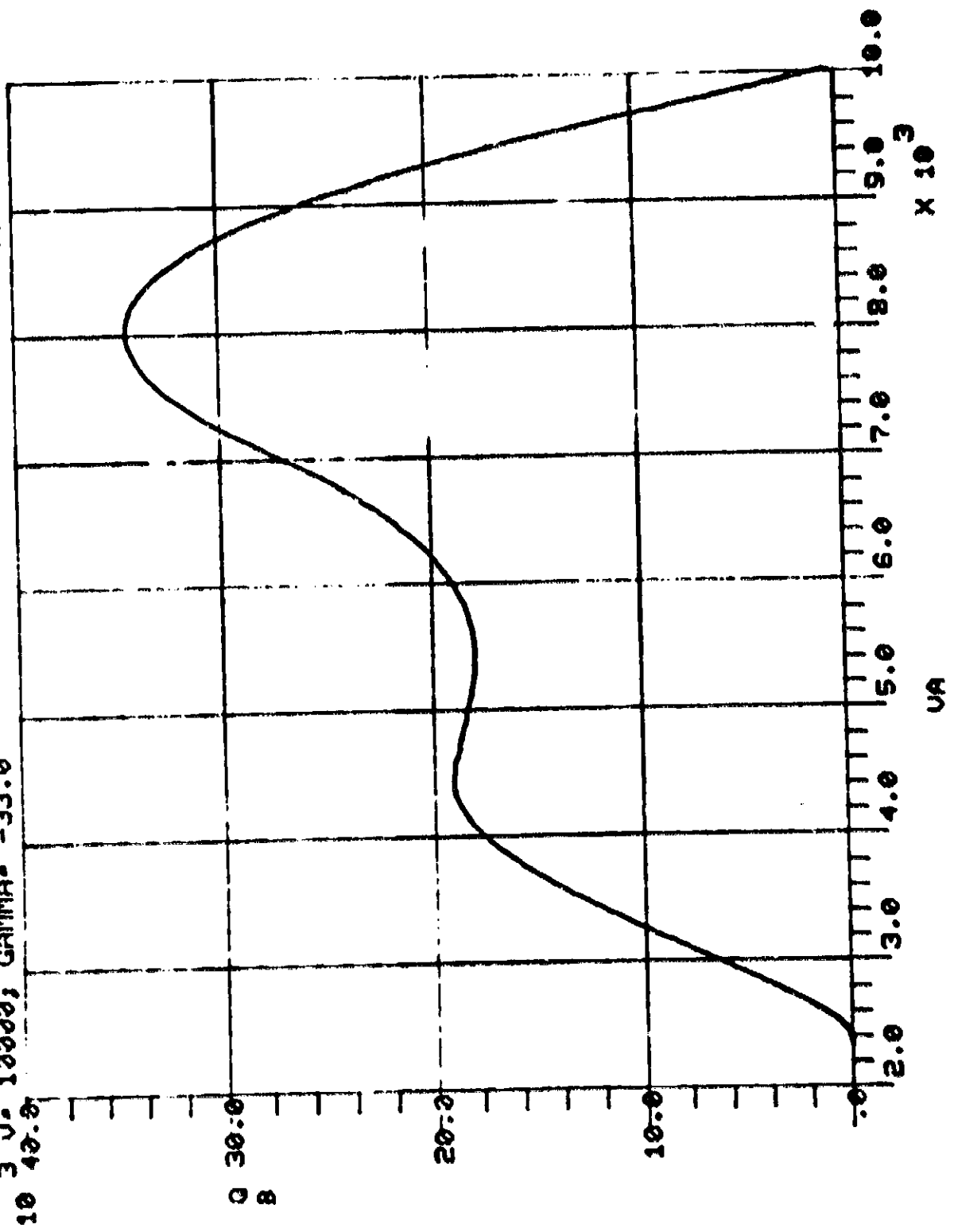
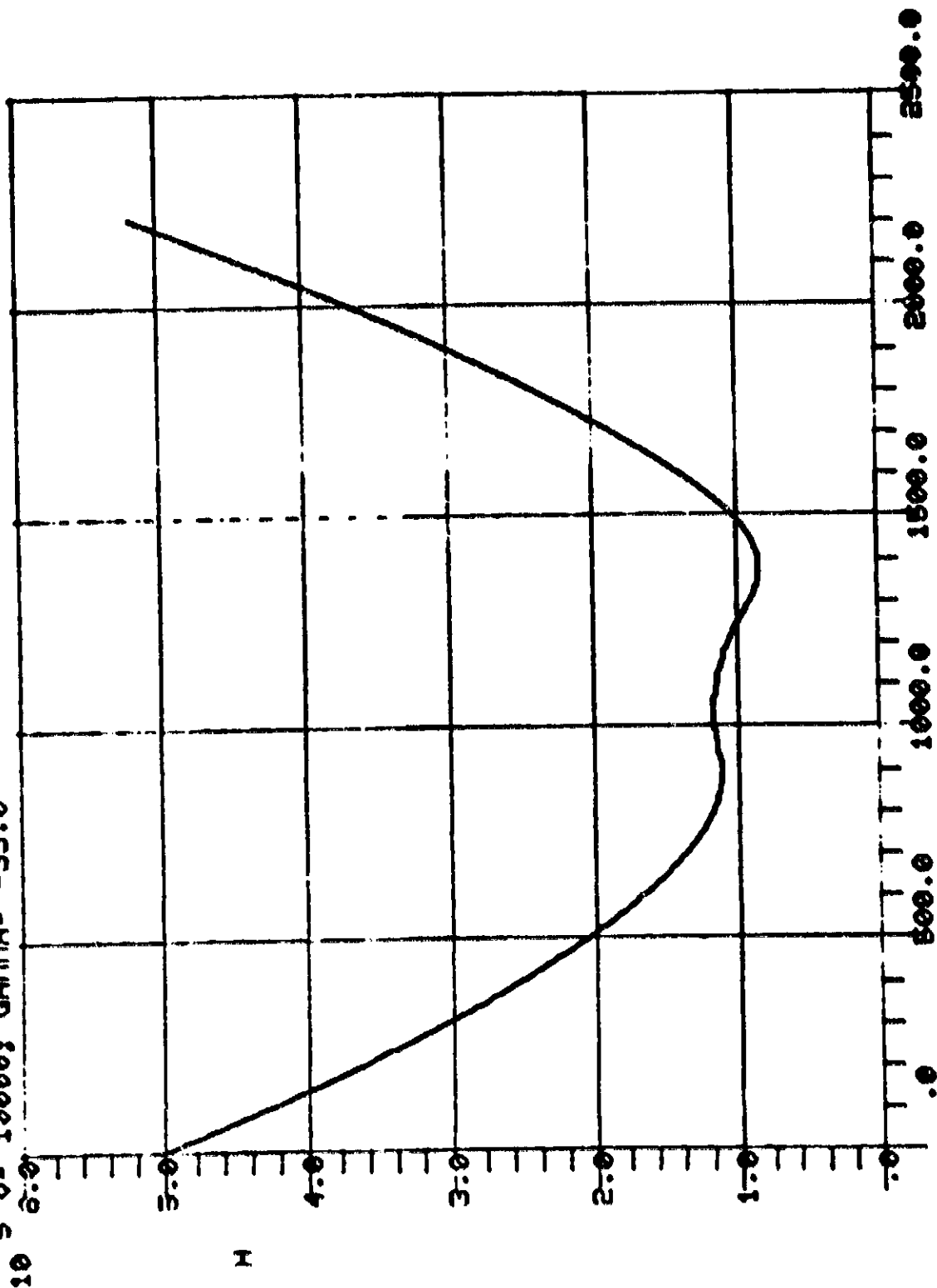


FIGURE A-55

09:04 JUN 05, '80

10 5 V- 12000; GAMMA- -33.0



DRNG

FIGURE A-56

10 5 U= 10000; GAMMA= -33.0

09:04 JUN 05, '80

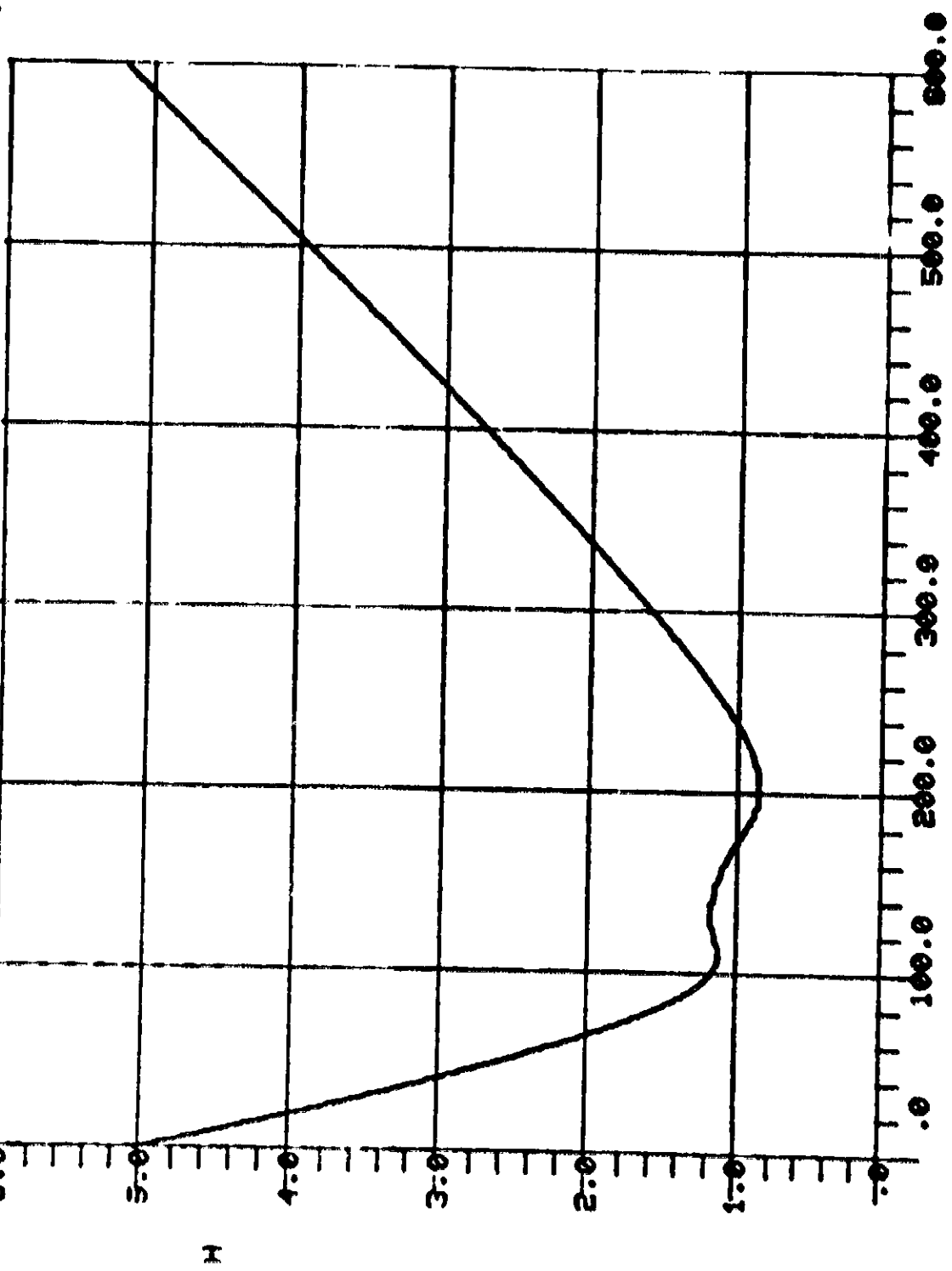


FIGURE A-5

09:04 JUN 05, '80

3 U= 10000; GAMMA= -33.0
10 12.0

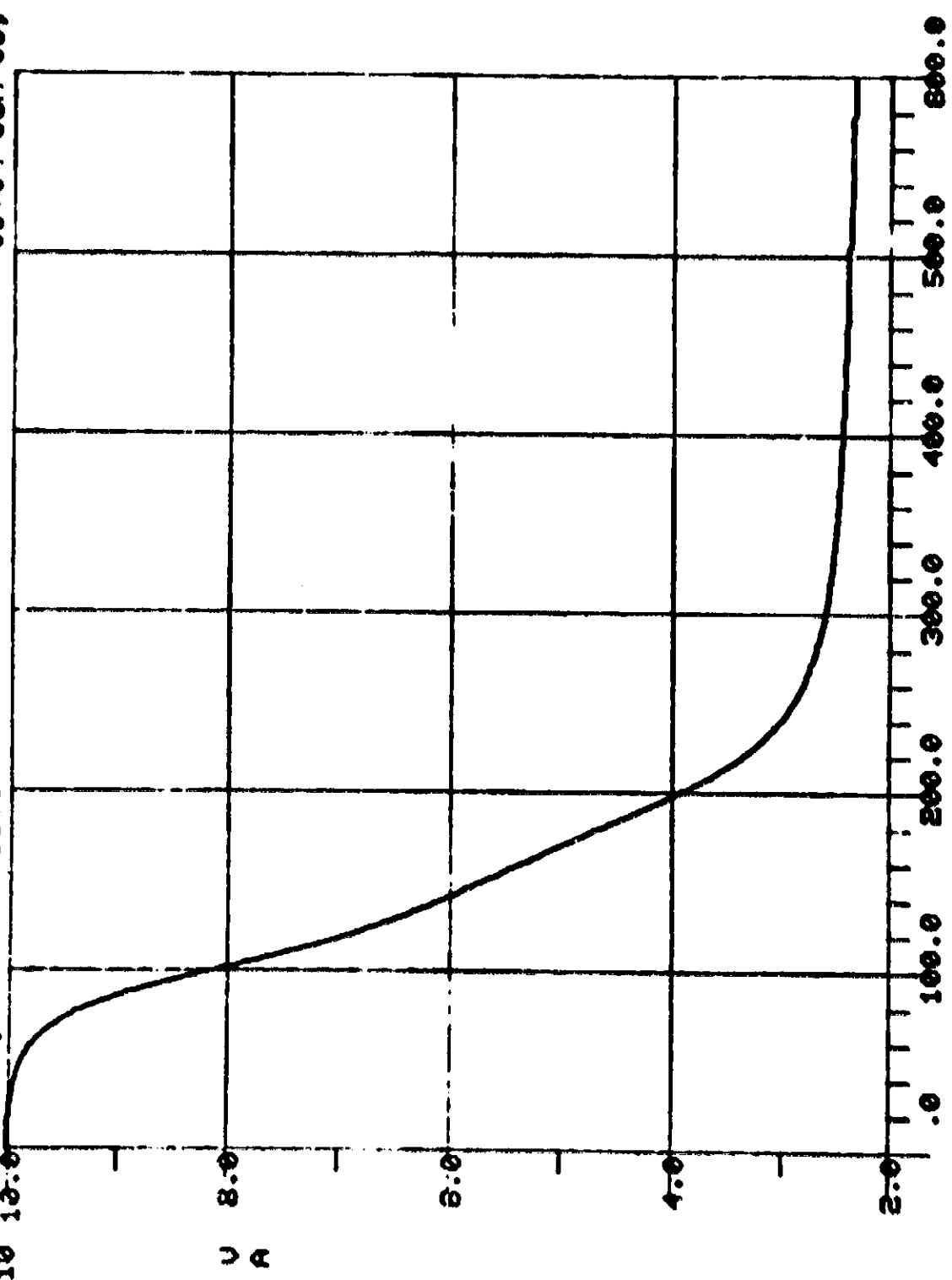
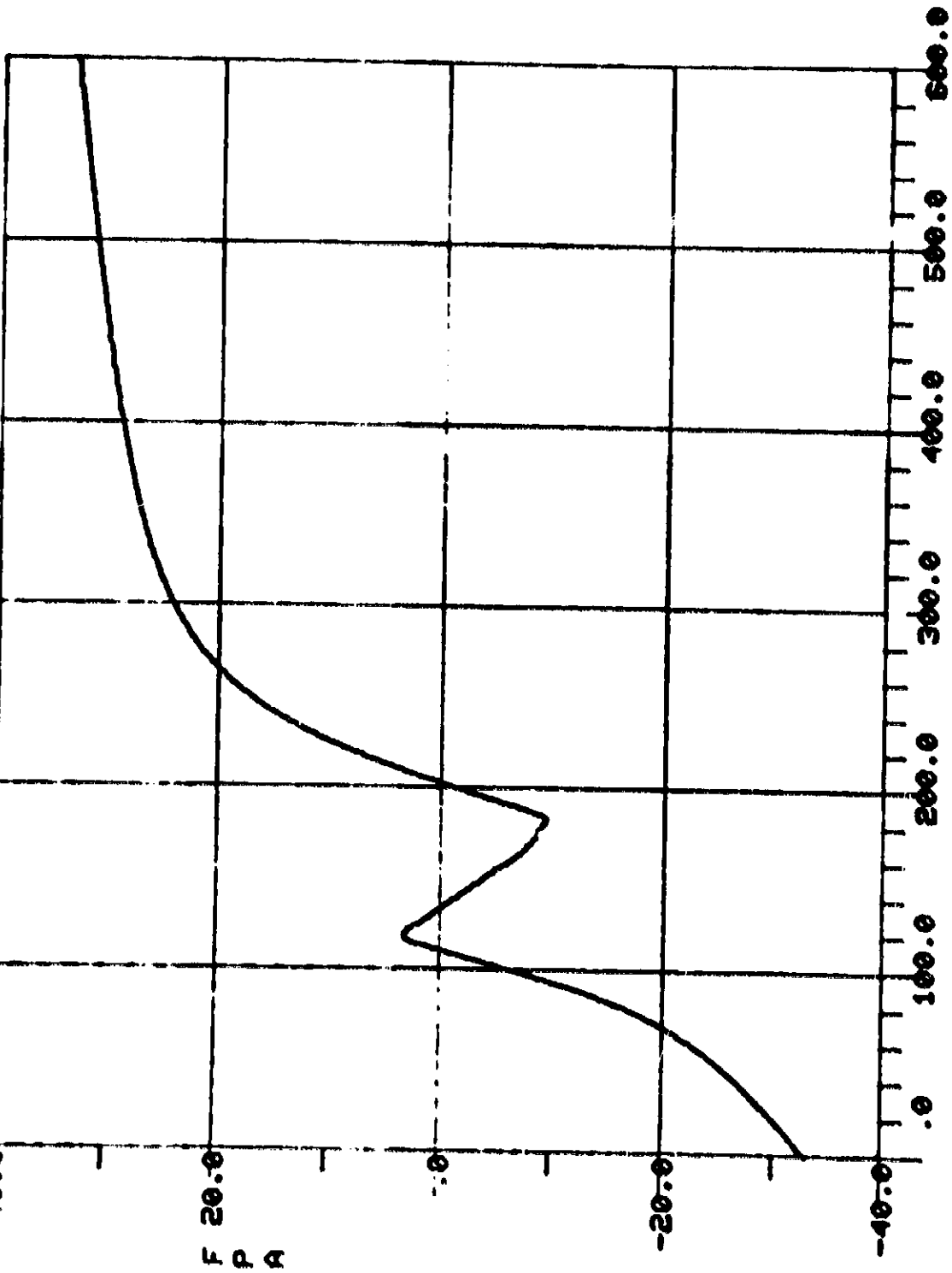


FIGURE A-58

09:04 JUN 05, '80

V= 12000; GAMMA= -33.0



T

FIGURE A-10

09:04 JUN 05, '80

V= 12000; GAMMA= -33.0

200.0

R100.0

G
C
D

-0

100.0

200.0

600.0

T

FIGURE 2-10

14:35 JUN 99, '80

3 1.3200, GAMMA=-23.5

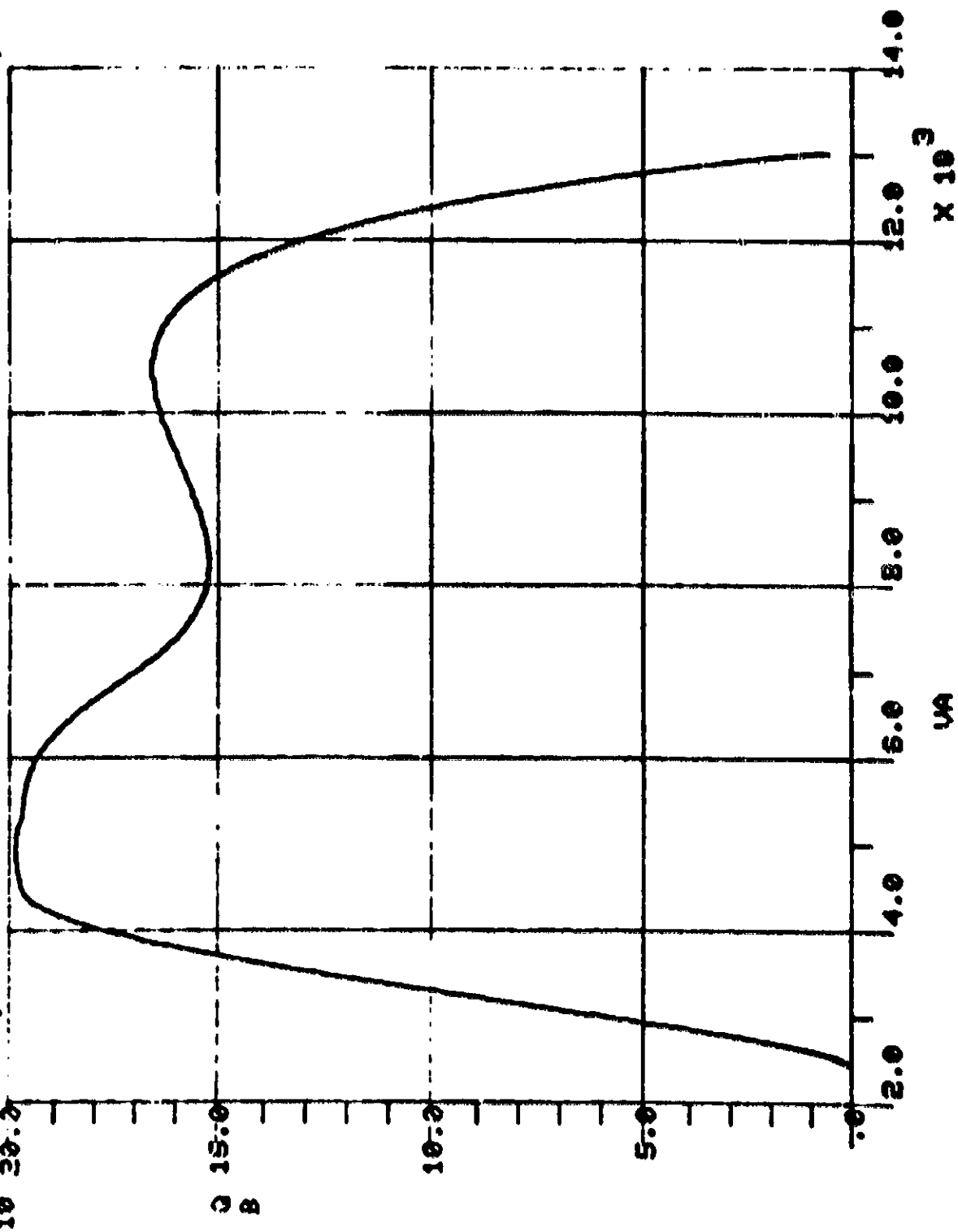
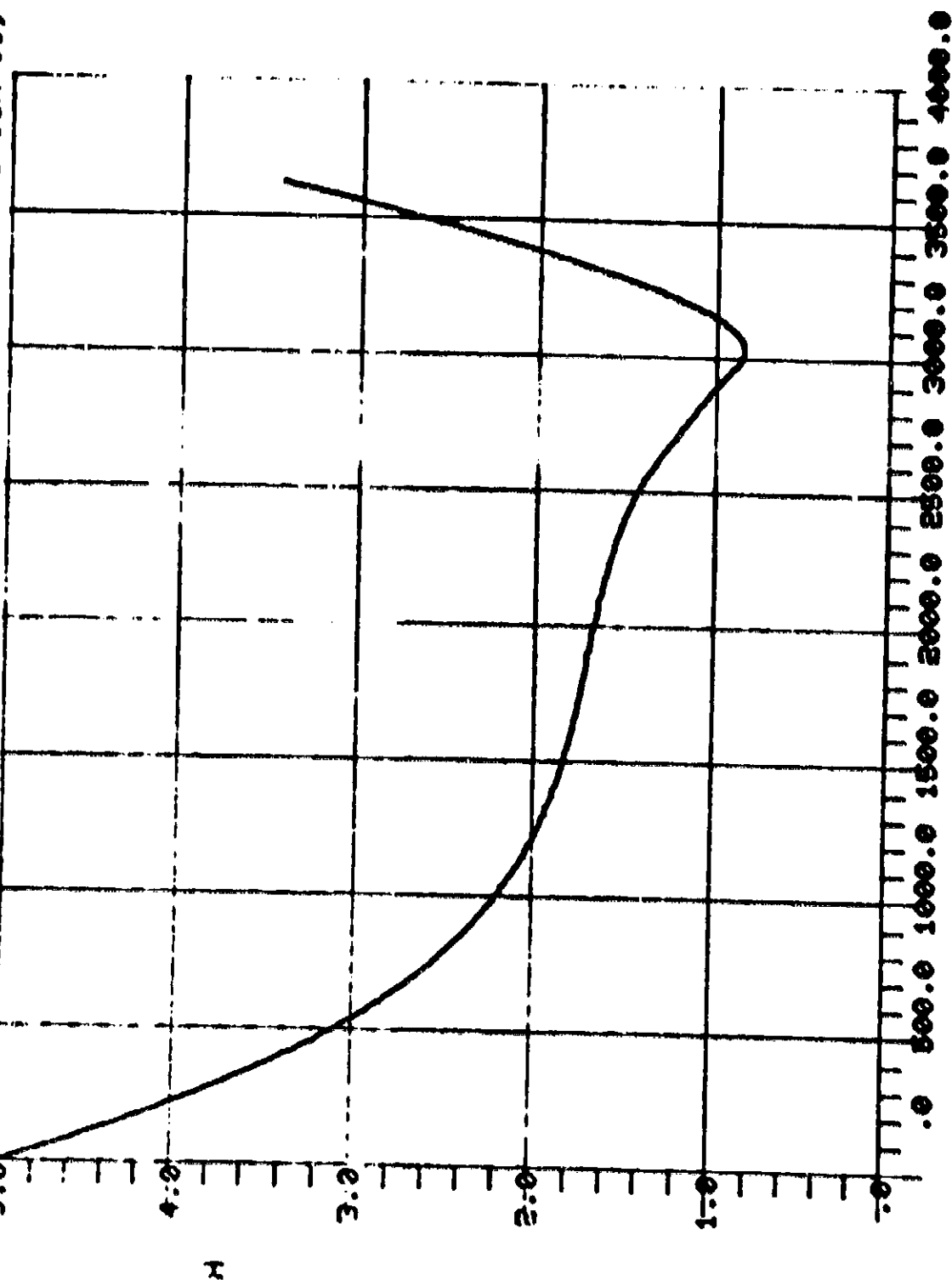


FIGURE A-61

10 5:00 3000, GAMMA--23.5

15:56 JUN 09, '63



DRNG

FIGURE A-60

14:35 JUN 09, '80

10 γ = 13200, GAMMA = -23.5

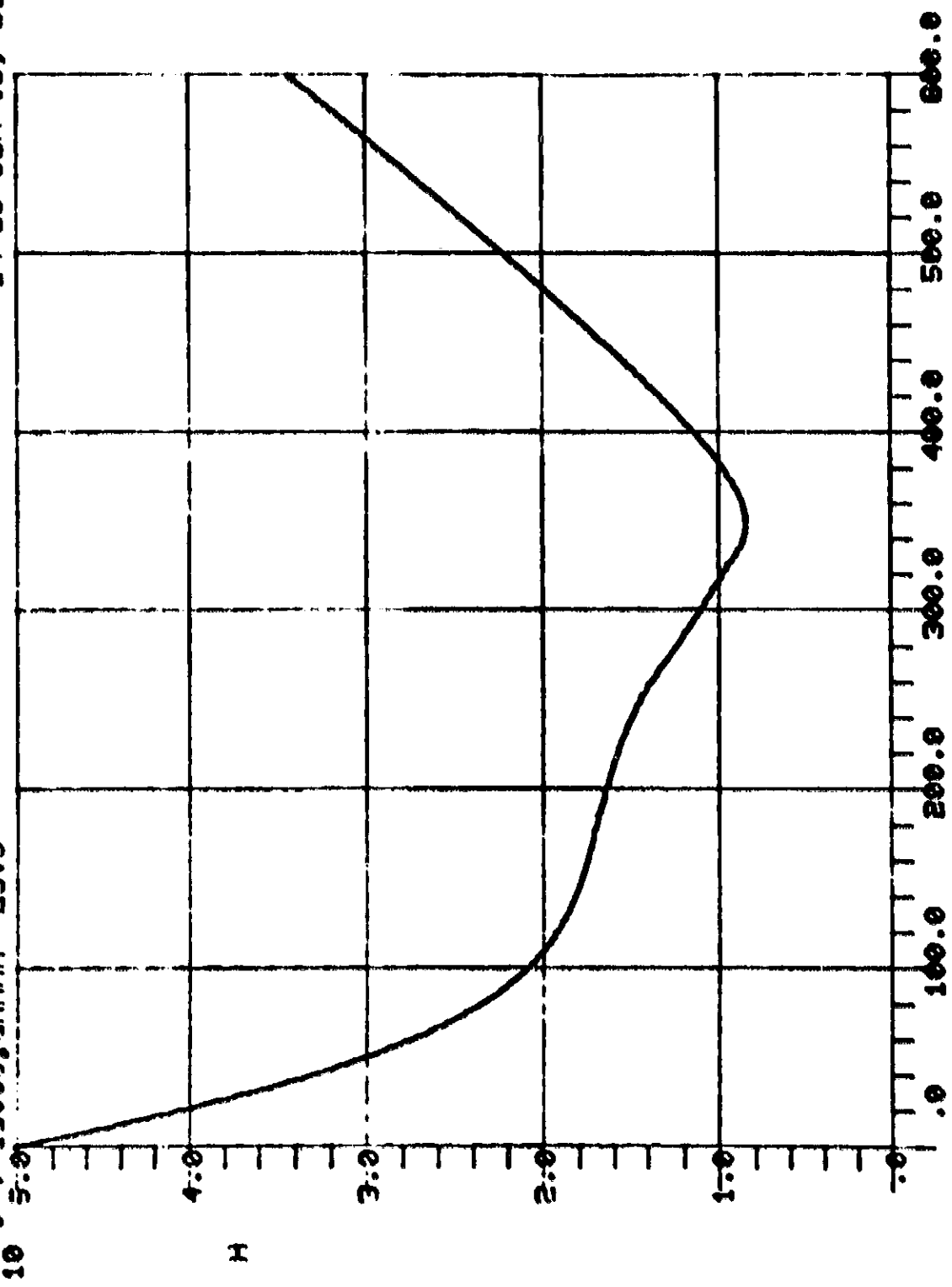
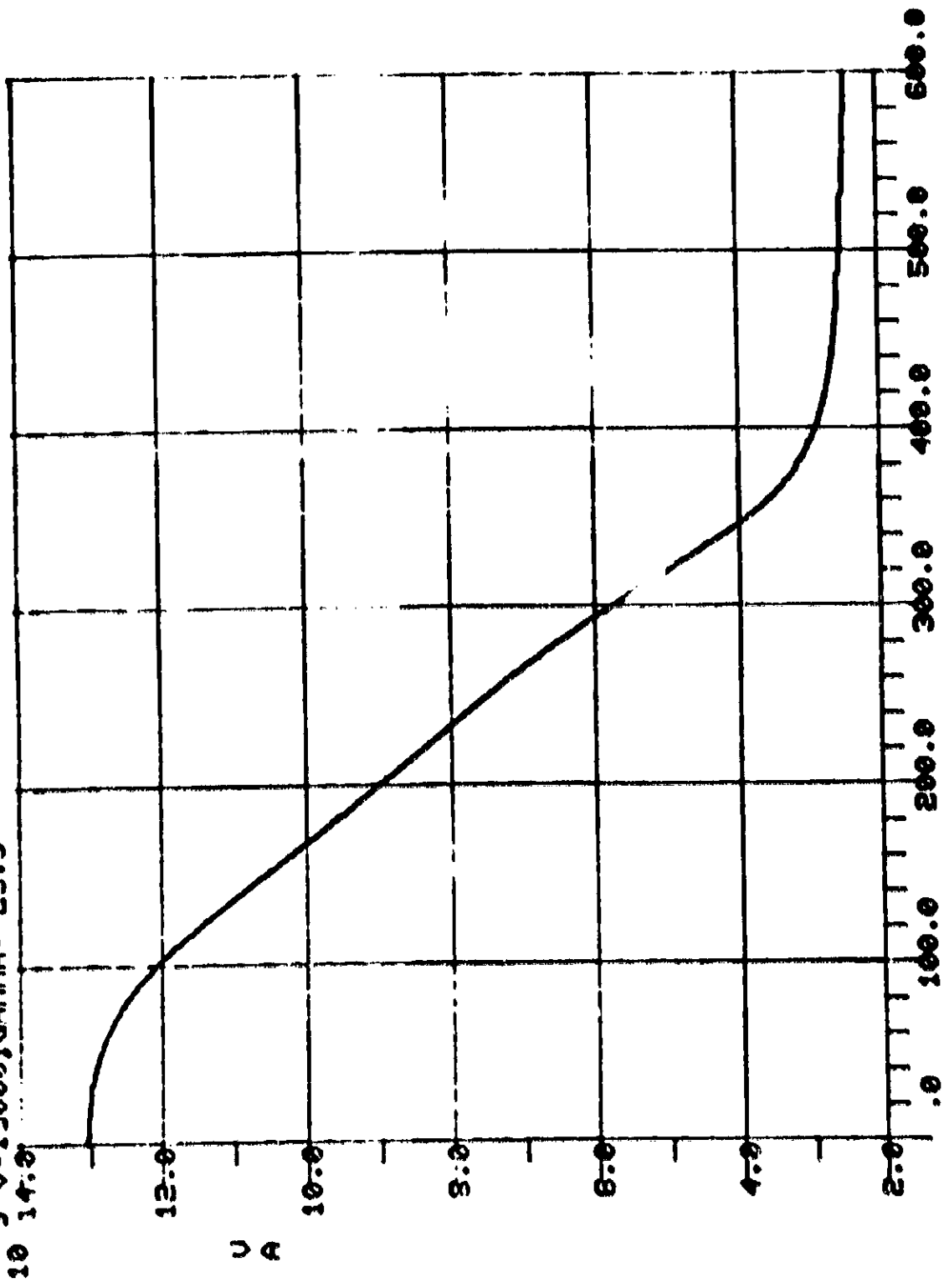


FIGURE A-60

15:56 JUN 09, '80

3 V-13000, GAMMA=-23.5

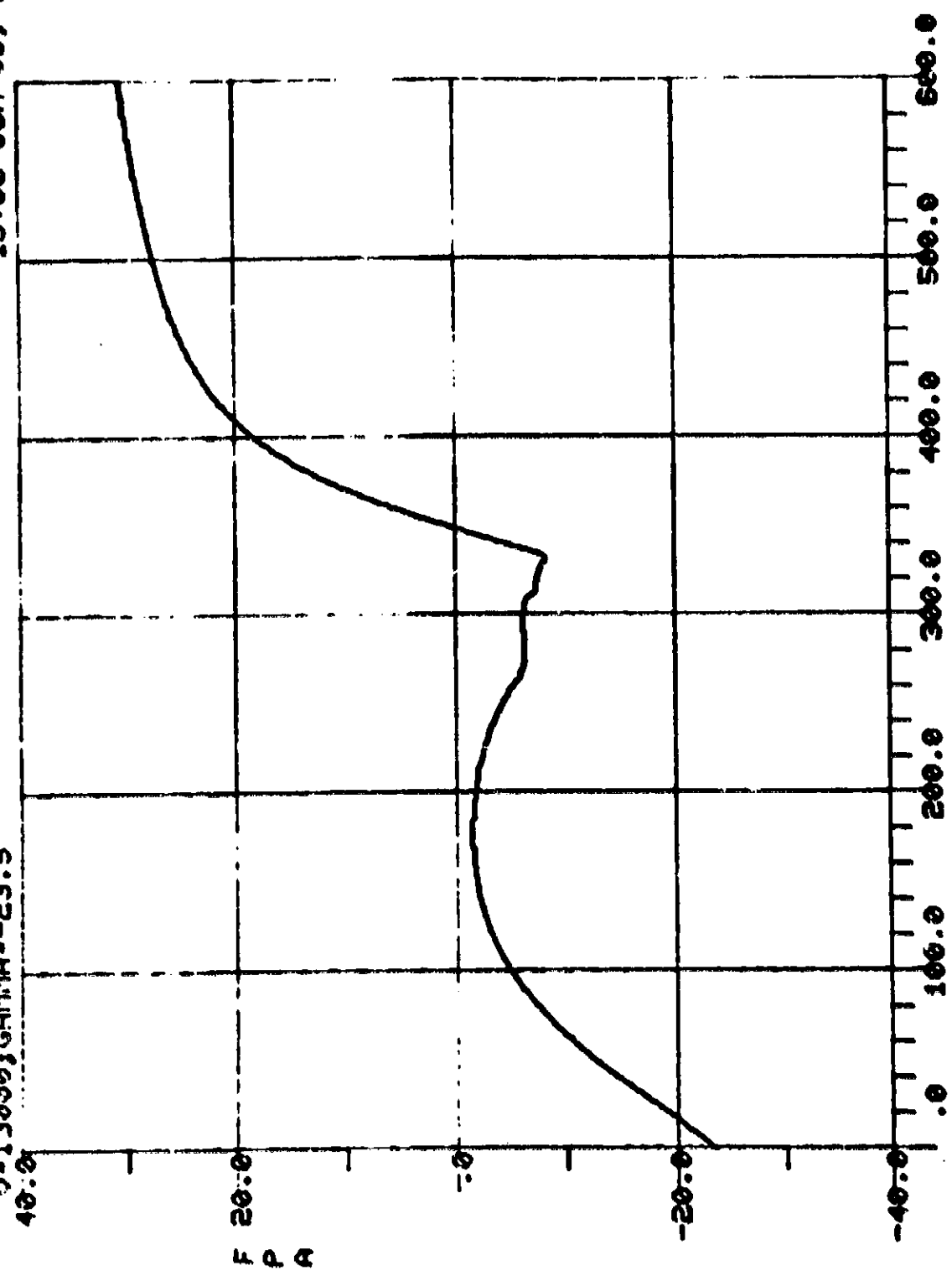


T

FIGURE 1-10

15:56 JUN 09, '80

U-13000; GAMMA=-23.5



T

FIGURE A-55

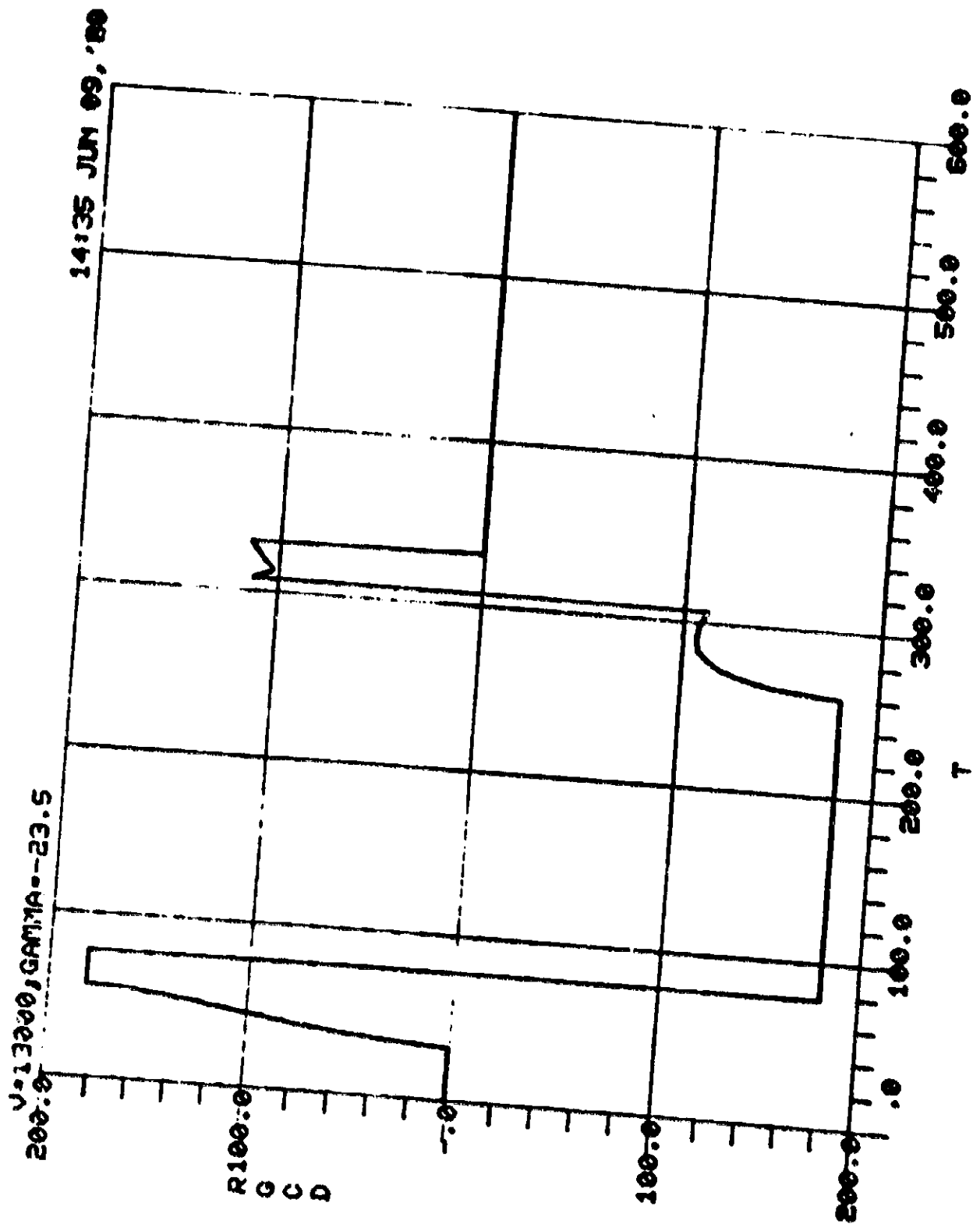
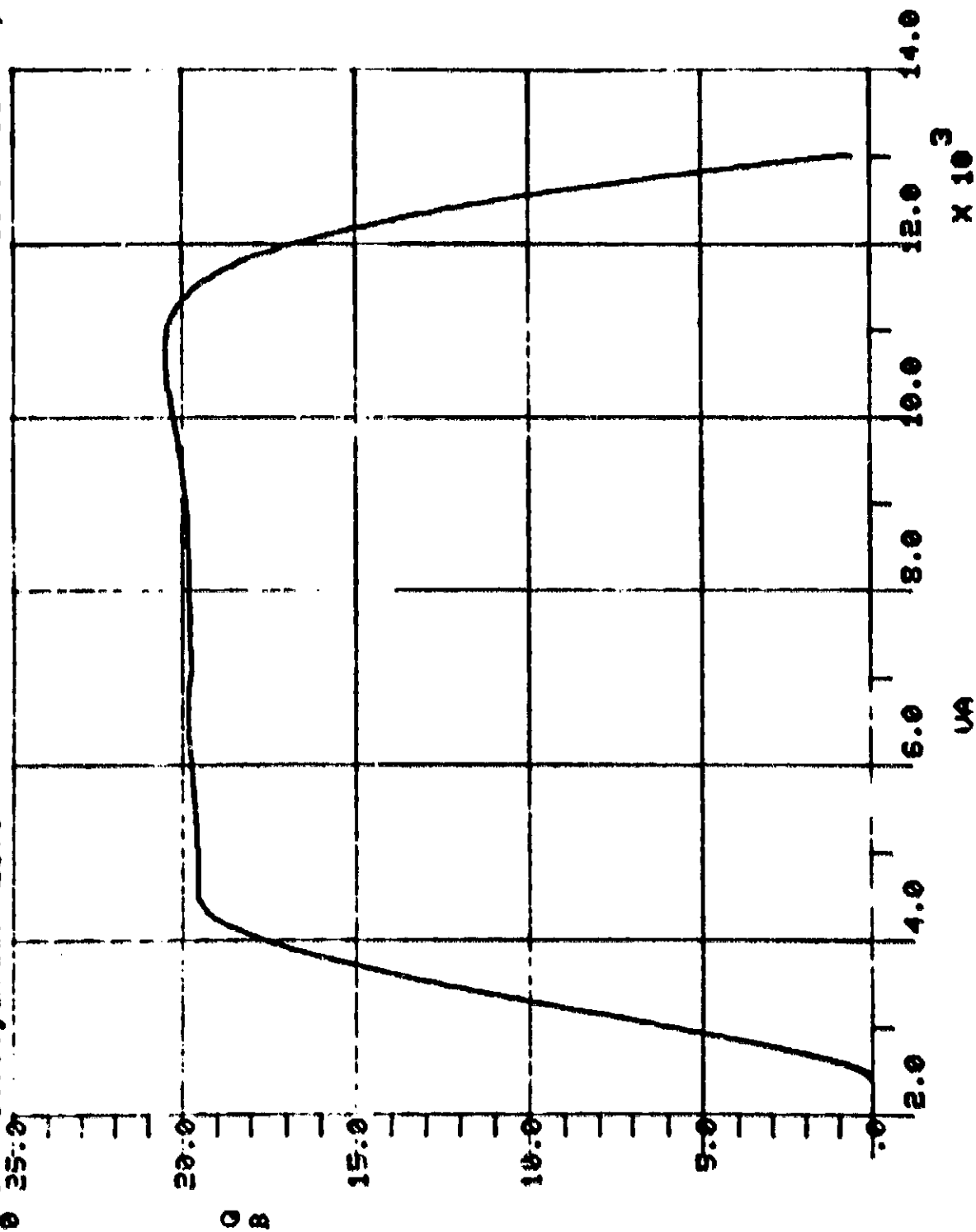
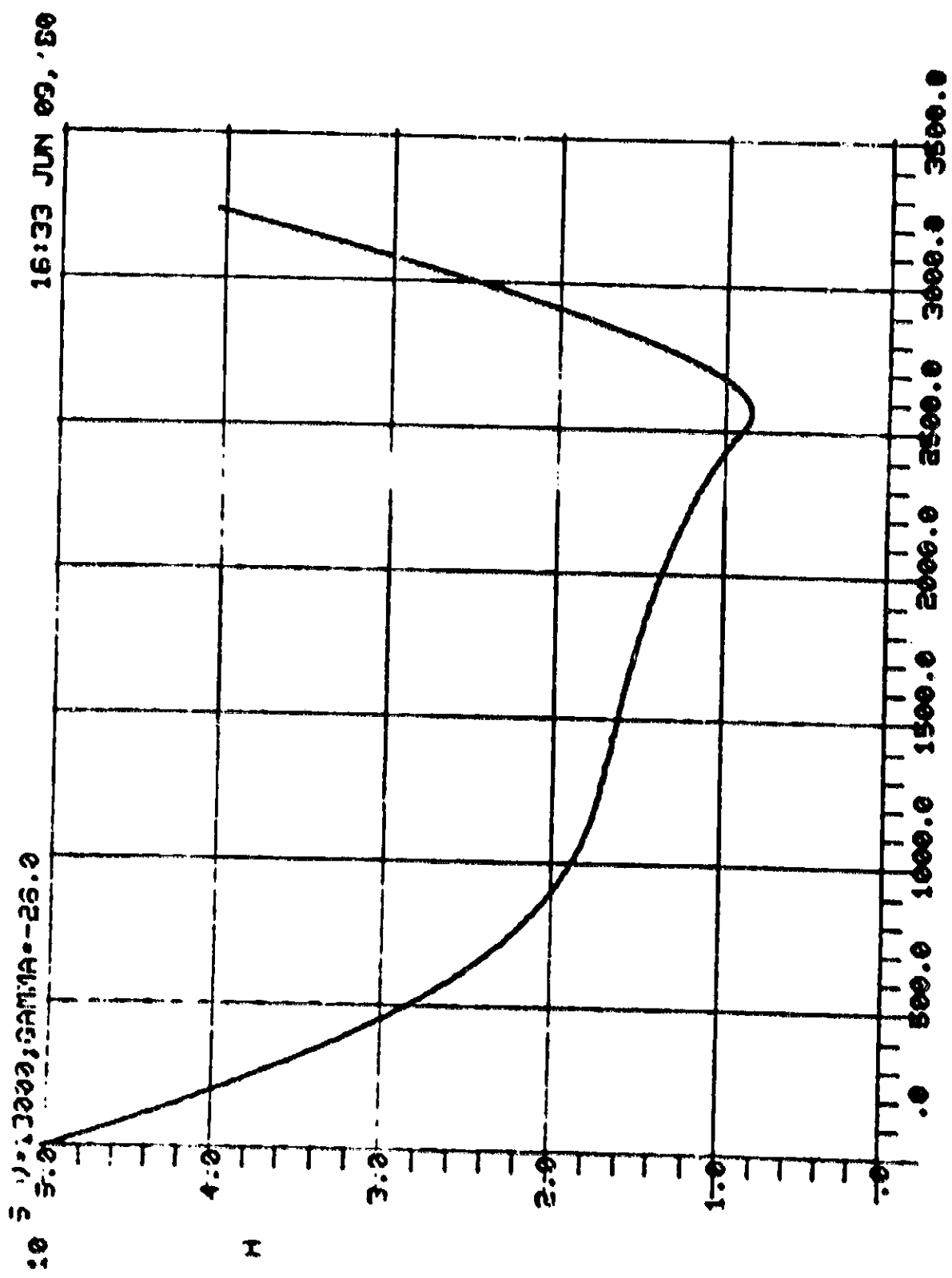


FIGURE A-55

3 10.13000, GAMMA = -26.0

13:26 JUN 09, '80



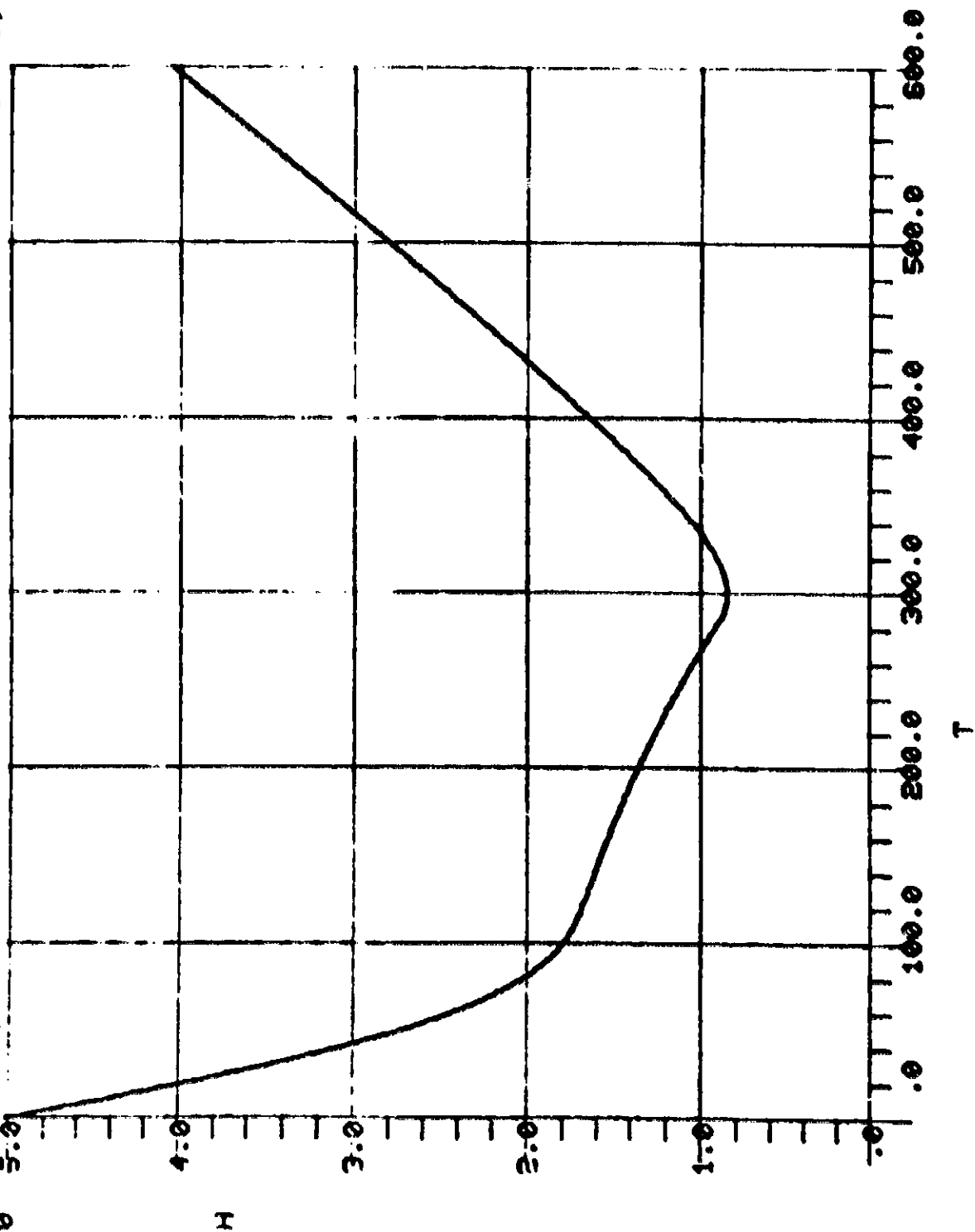


DRING

FIGURE 1.00

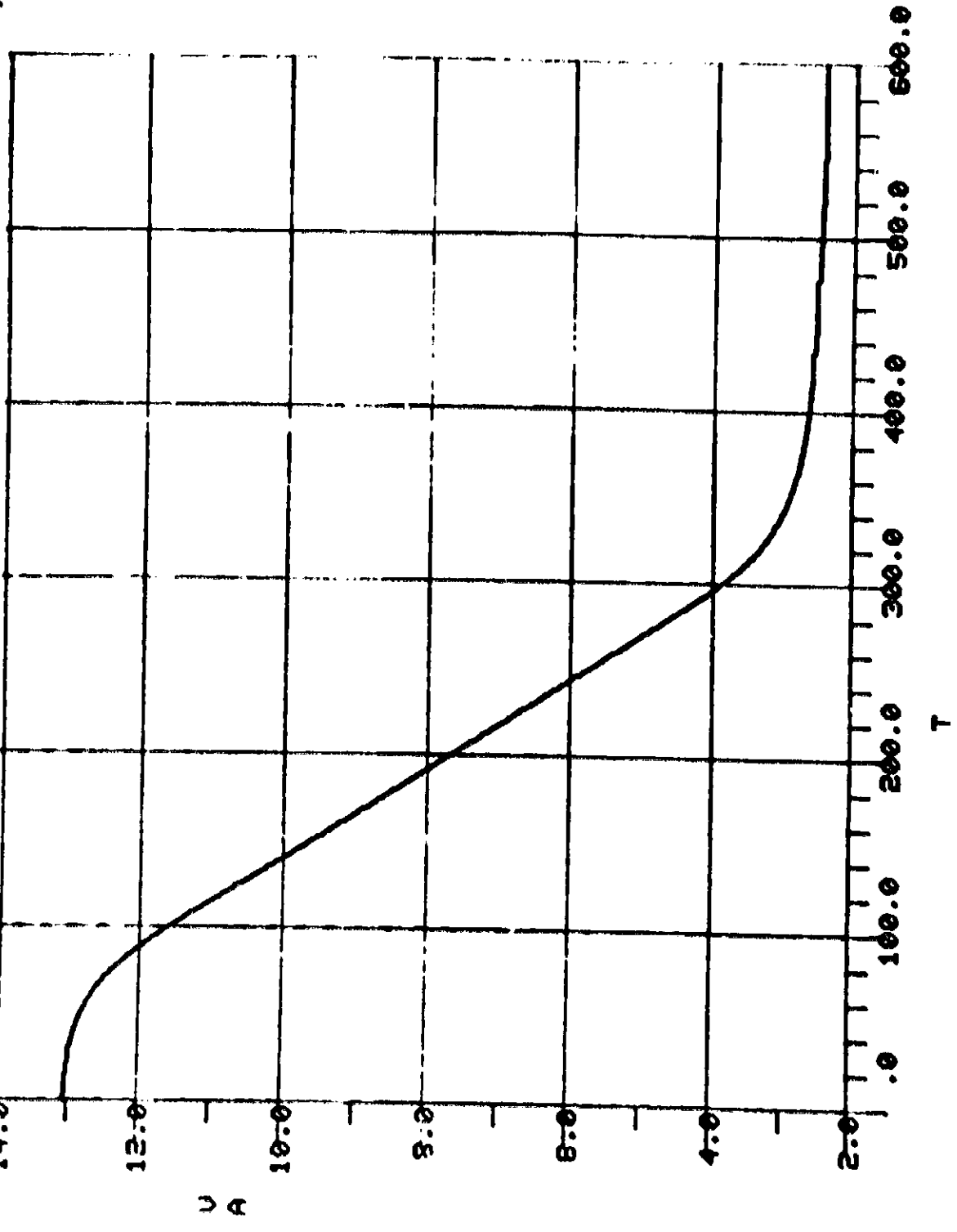
13:26 JUN 09, '80

10 5:0 V=13000; GAMMA=-26.0



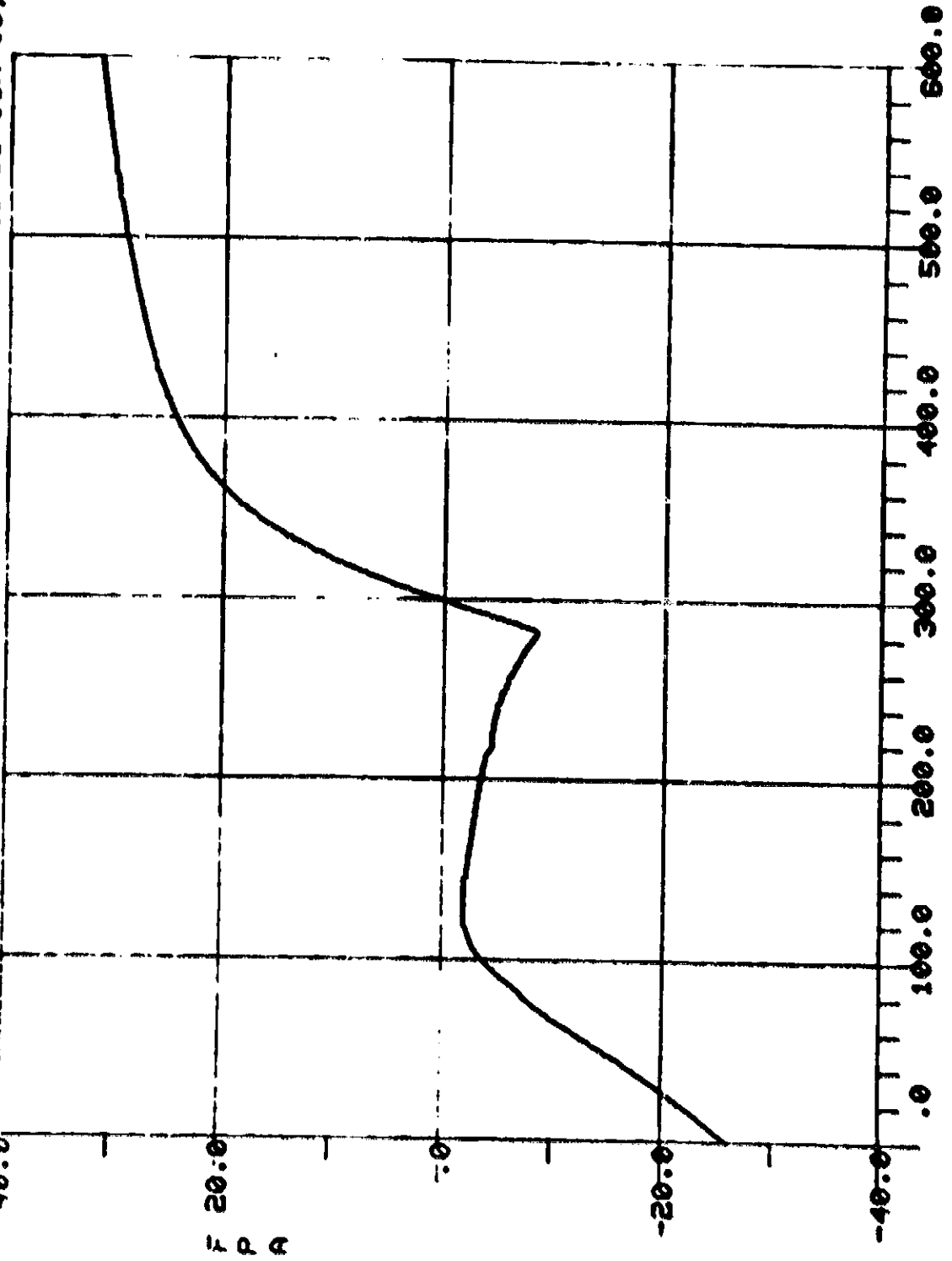
16:33 JUN 09, '80

10 3 U-13000; GAMMA-25.0
14.0



16:33 JUN 09, '80

V=2300; GAMMA=-26.0



T
PLATE 3-1

13:26 JUN 09, '80

U.13000;GAM:1A-26.0

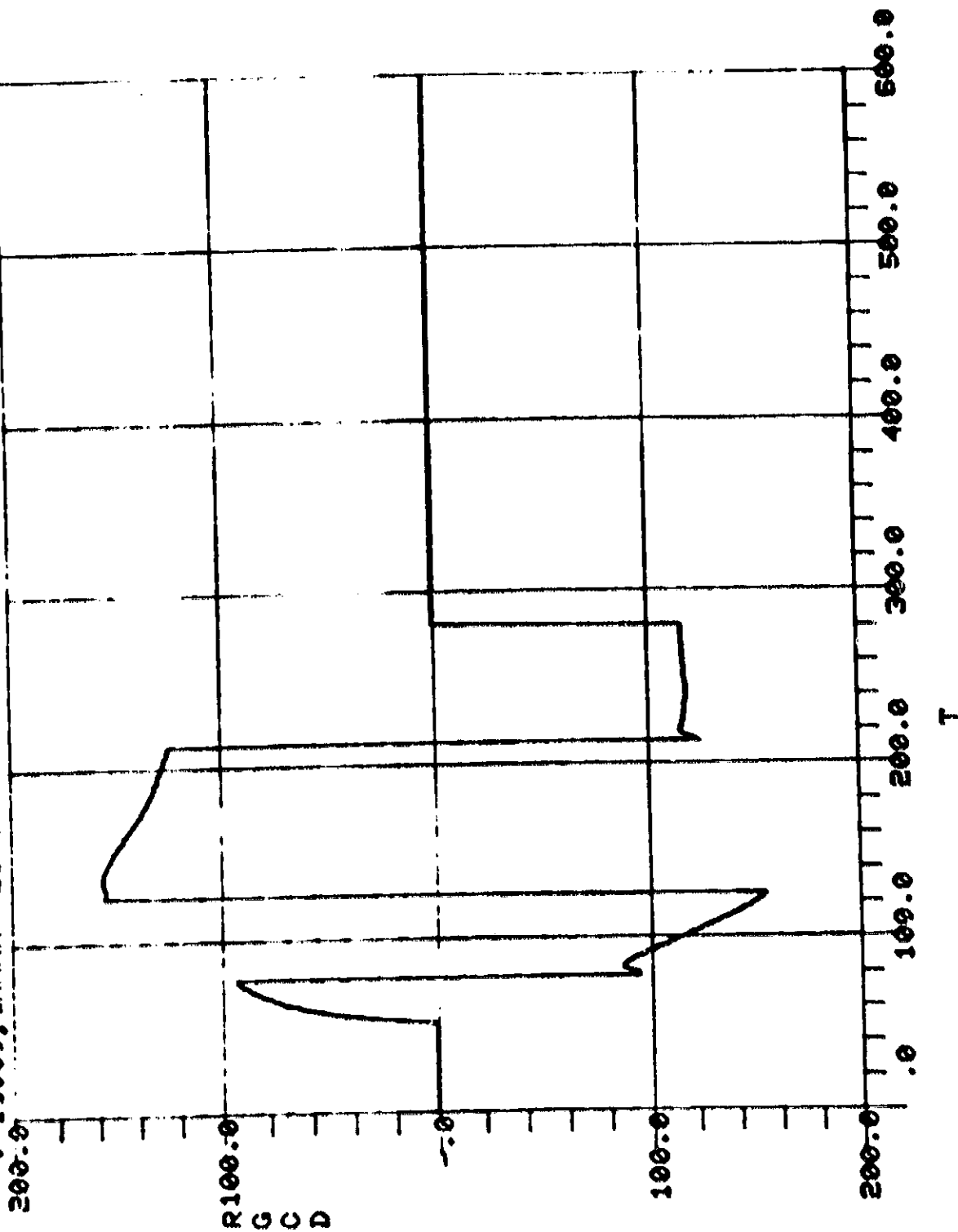
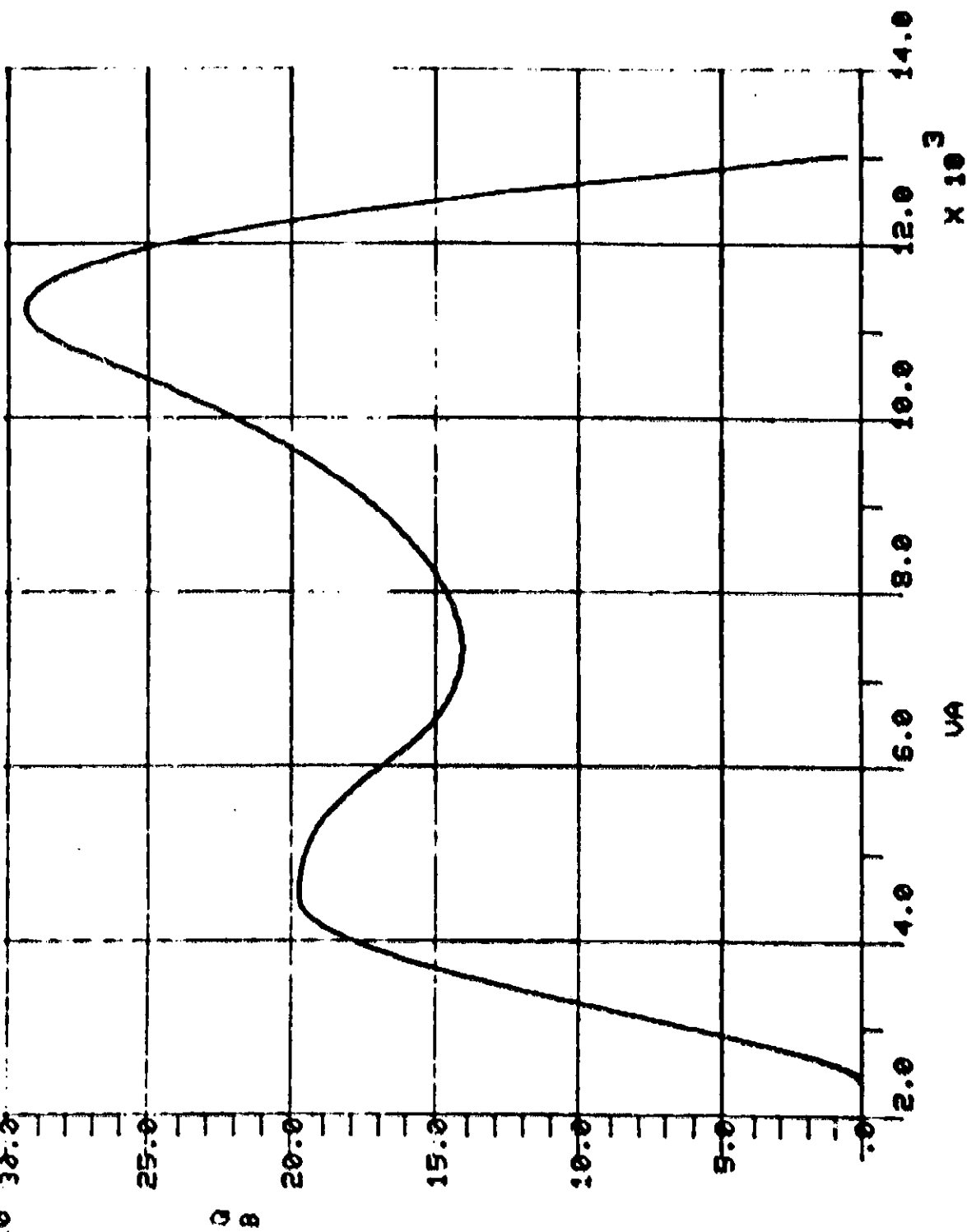


FIGURE 1-20

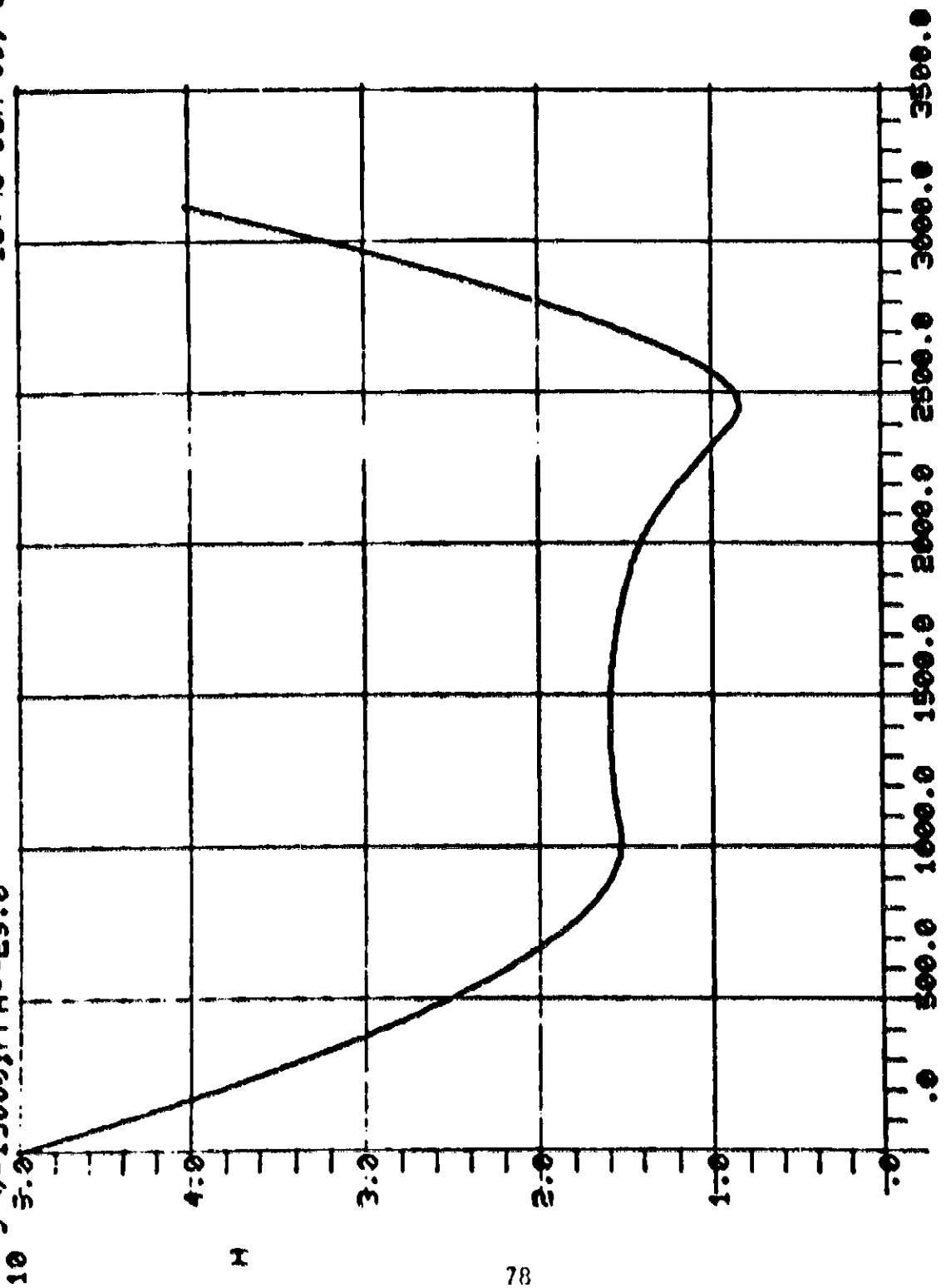
10 38.0 3 U-13000; GAM:1A--23.0

13:56 JUN 09, '80



16:45 JUN 09, '80

10 5:0 13000, FPA--23.0



DRNG

Figure 1-2

10 5.0 U-13200; GAMMA--29.0

13:56 JUN 09, '80

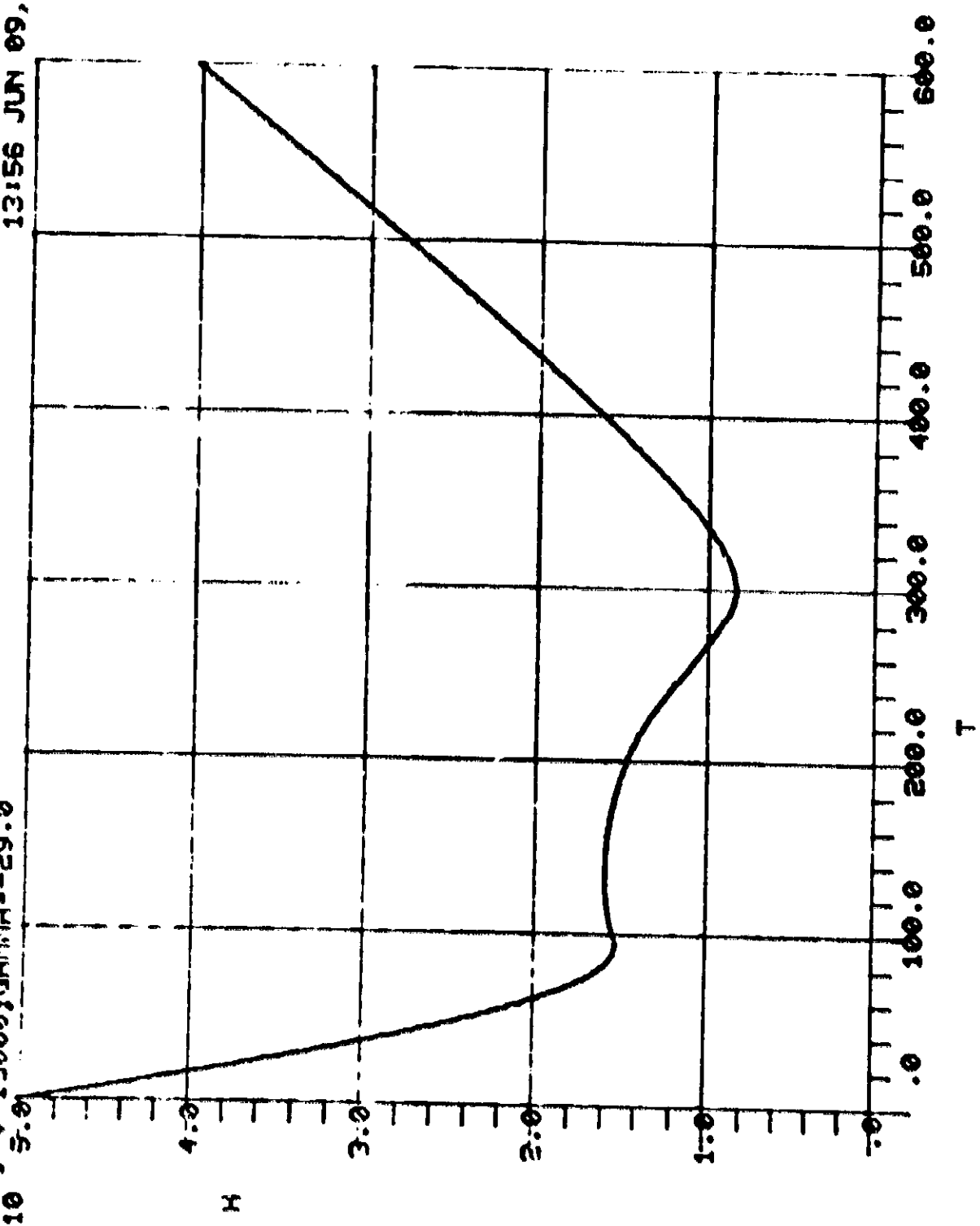


Figure 1.1.1

10 14:0 3 U-13000; FPA--29.0 16:45 JUN 09, '80

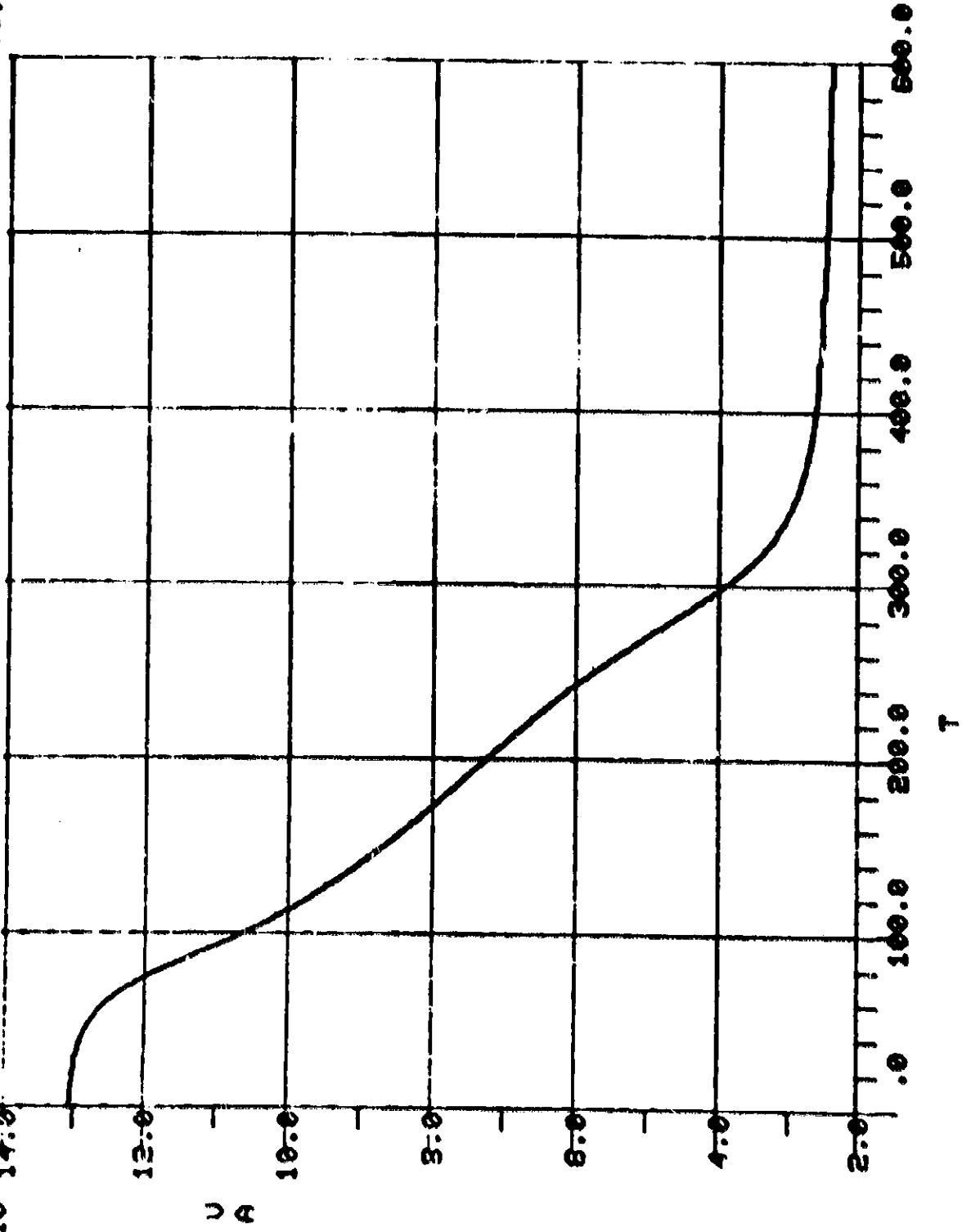
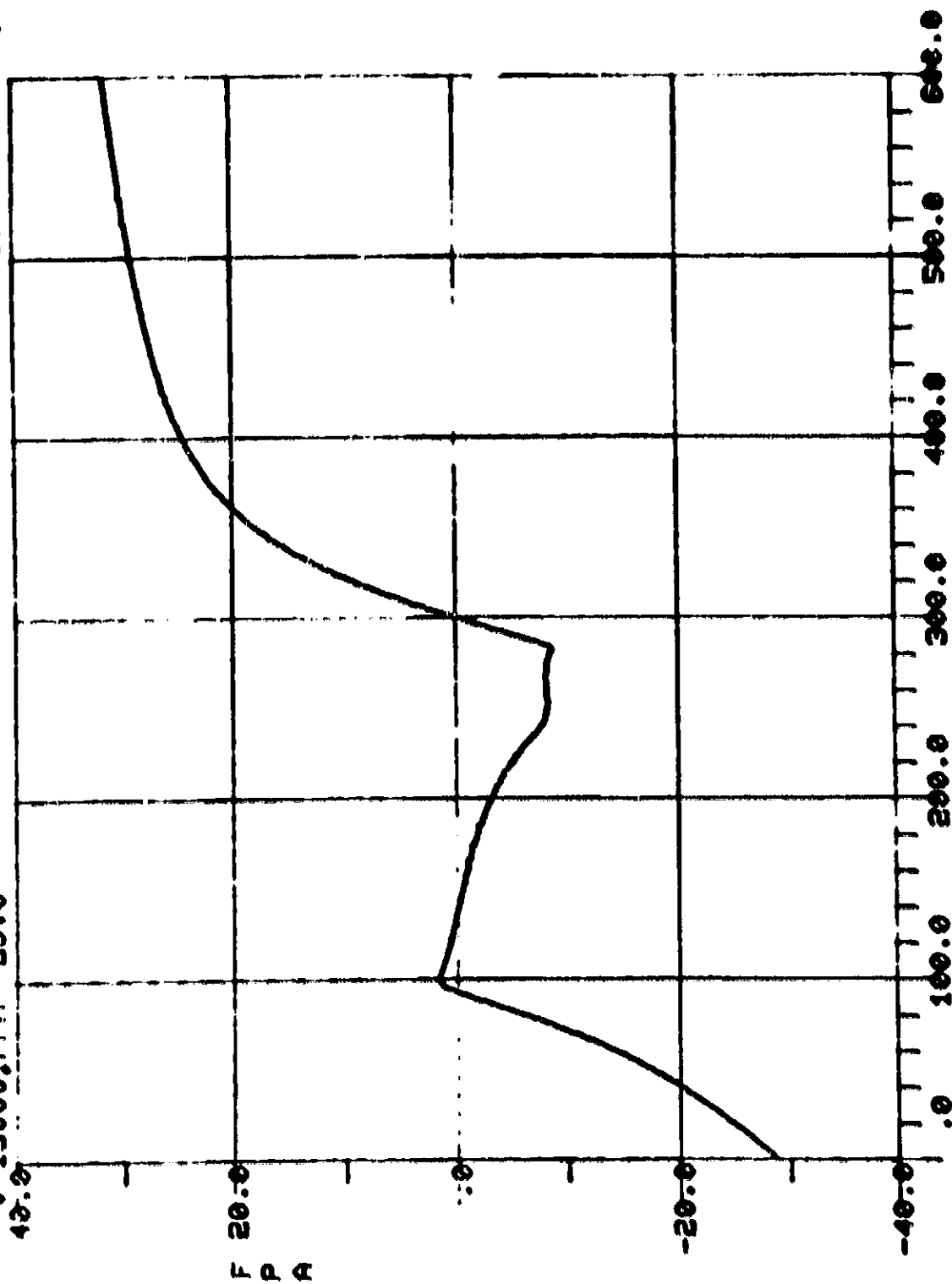


FIGURE 1-18

16:45 JUN 09, '80

V-13000; FPA--29.0

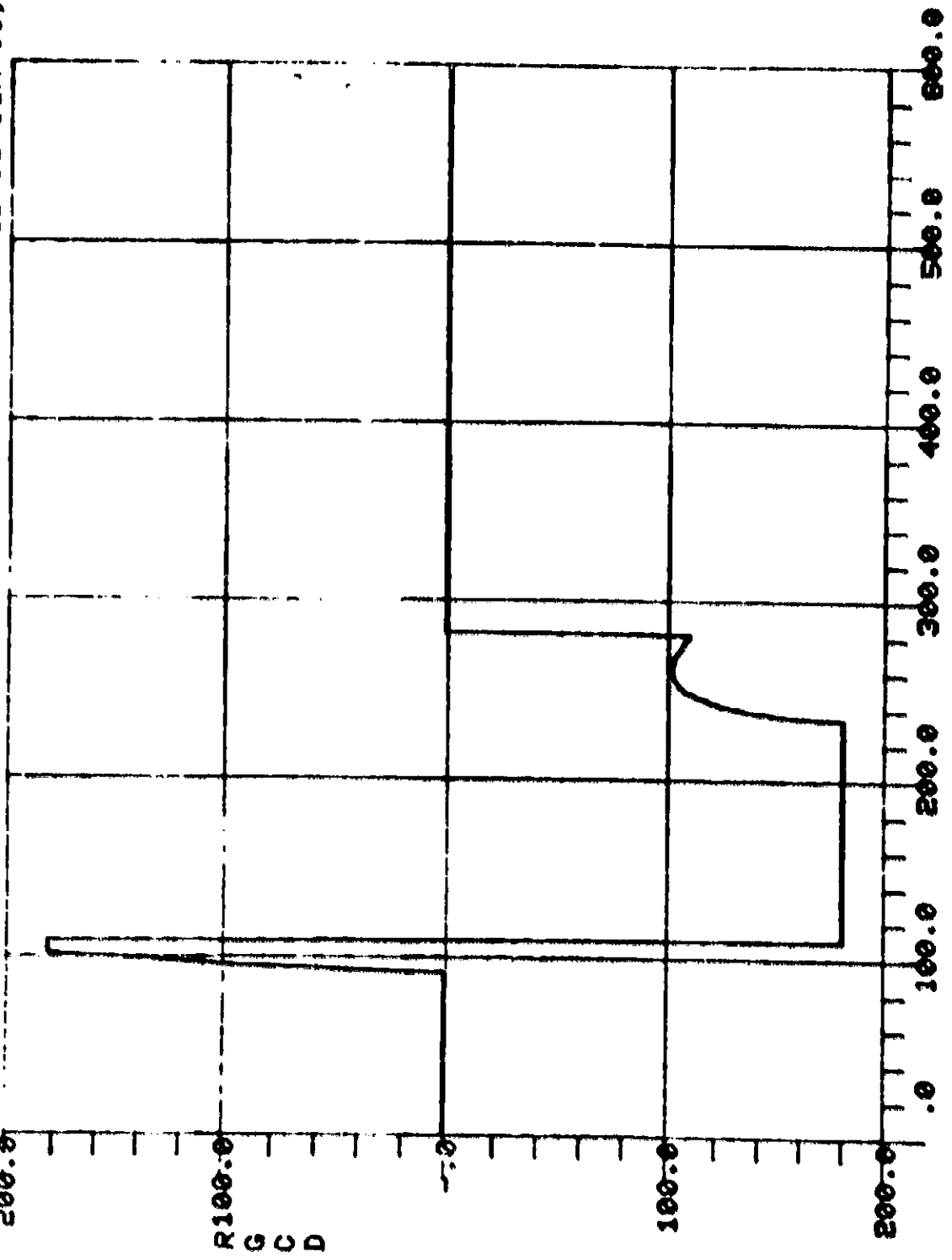


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FIGURE 4-27

13:56 JUN 09, '80

U-13000; GAMMA=-29.0



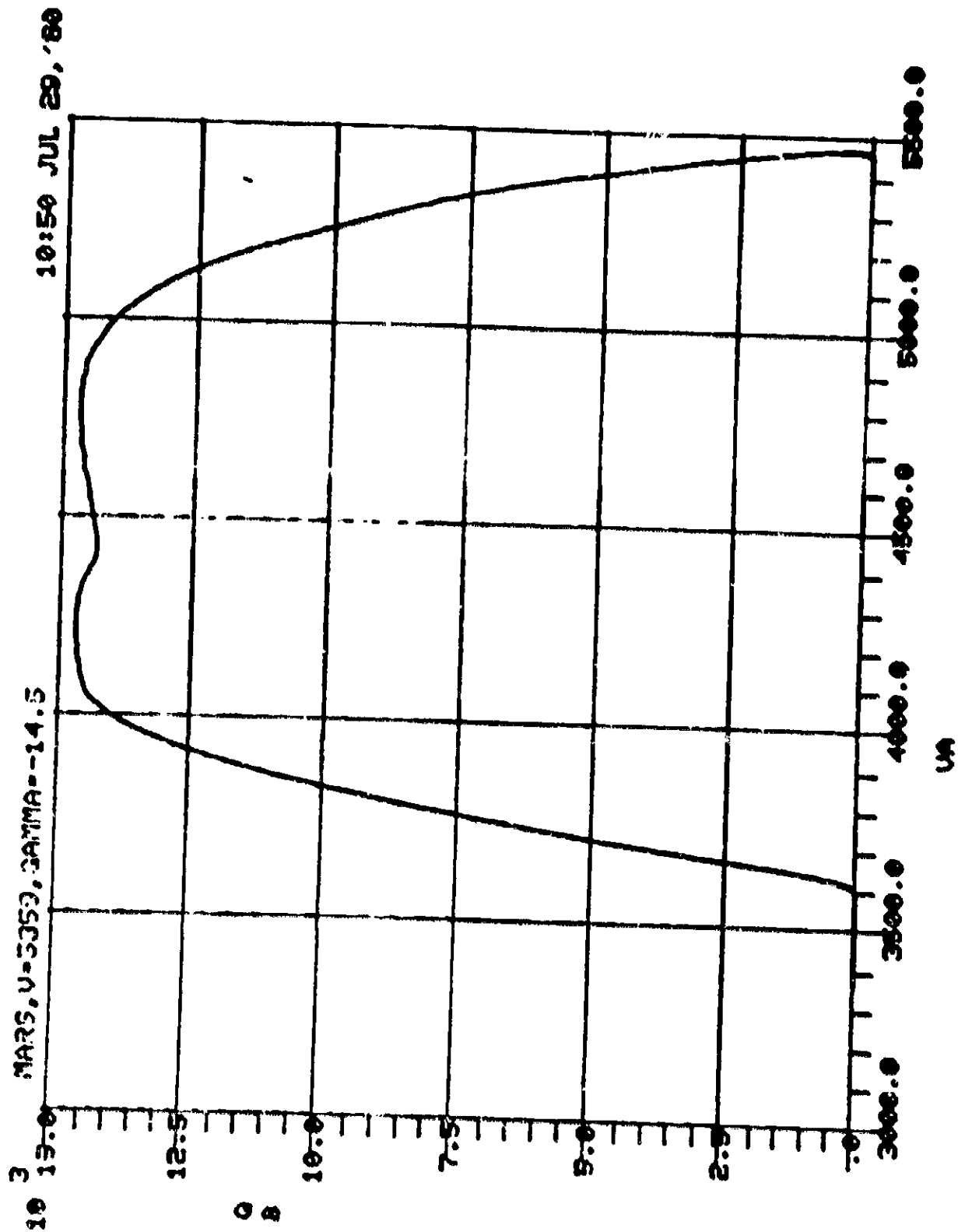
T

FIGURE A-29

APPENDIX B
MSR TRAJECTORIES

The following Mars atmospheric entry trajectories are included in this Appendix:

<u>Entry Velocity</u> <u>(m/sec)</u>	<u>Flight Path Angle</u> <u>(degrees)</u>	<u>Figures</u>
5359	-14.5	B1 through B9
5359	-15.5	B10 through B18
5359	-16.5	B19 through B27



10:50 JUL 29, '80

MARS, U=5359, GAMMA=-14.5

10 30.0

25.0

H

20.0

15.0

10.0

5.0

0.0

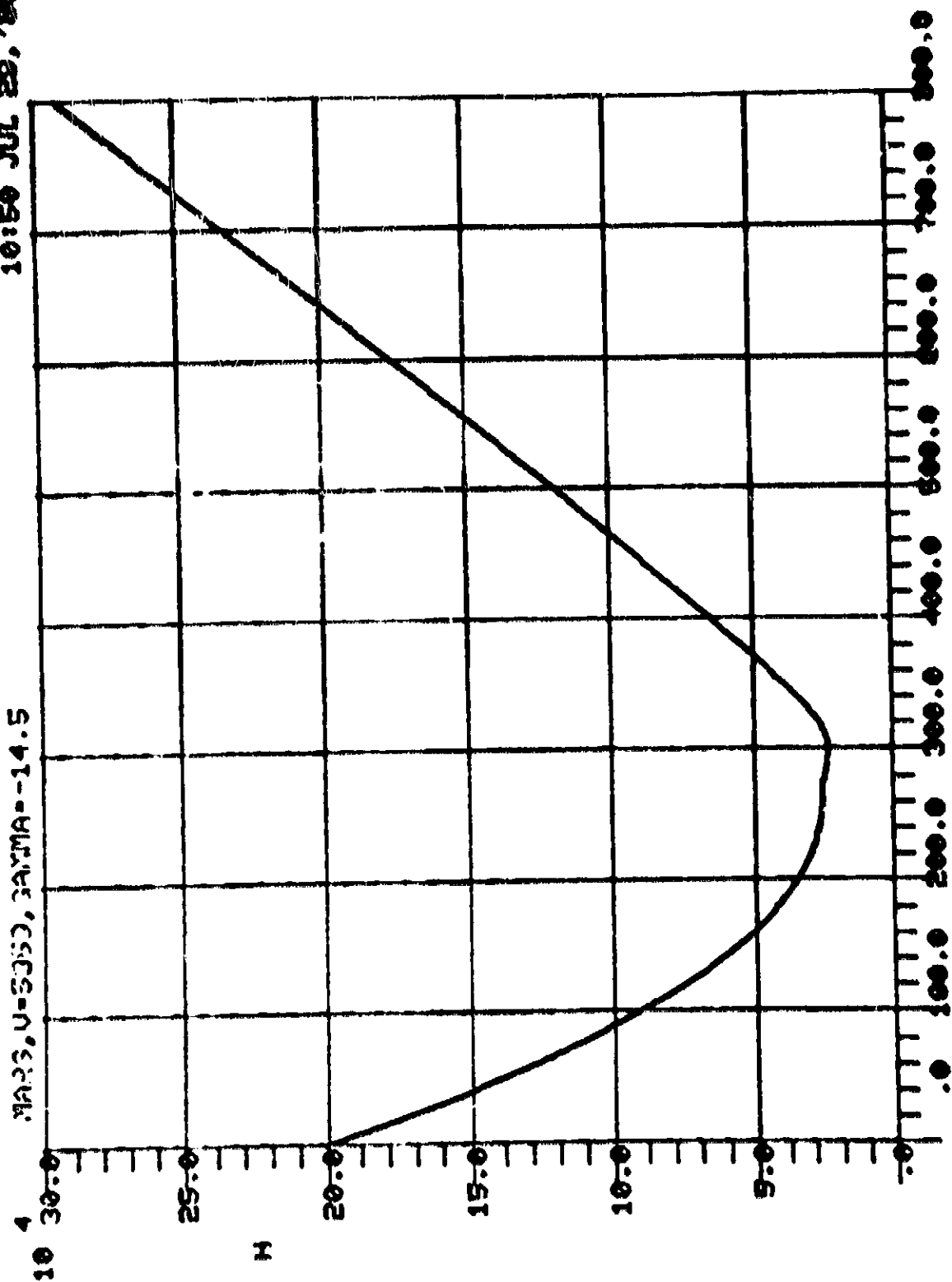
0.0 500.0 1000.0 1500.0 2000.0 2500.0 3000.0 3500.0

DRNG

FIGURE 10

10:50 JUL 29, '80

MASS, U=5353, 3A, MA=-14.5



10:50 JUL 29, '80

MARS, U=5359, GAMMA=-14.5

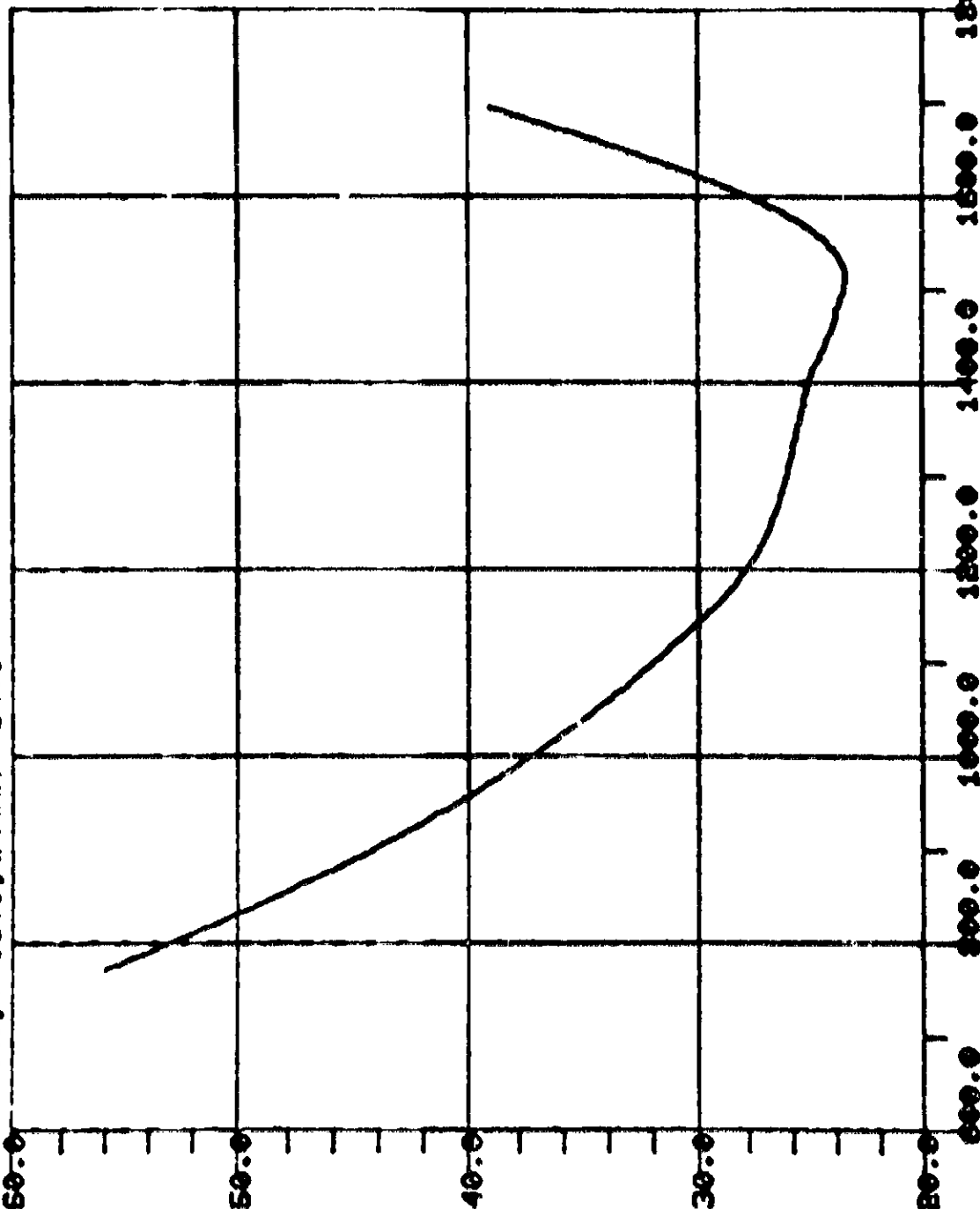
10 50.0

H 50.0

40.0

30.0

20.0



DONG

10:50 JUL 29, '80

MARS, U=5353, GAMMA=-14.5

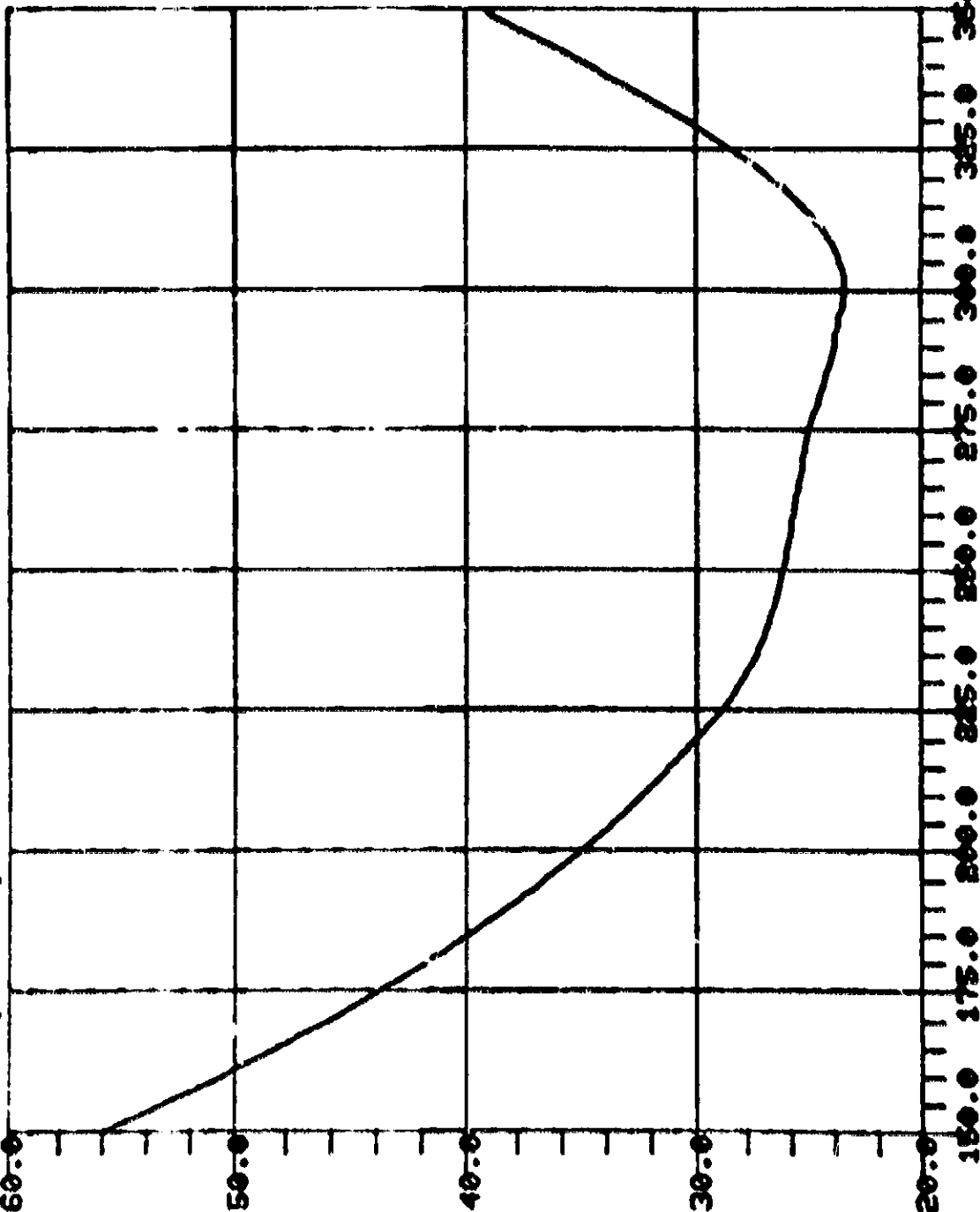
10 60.0

H 50.0

40.0

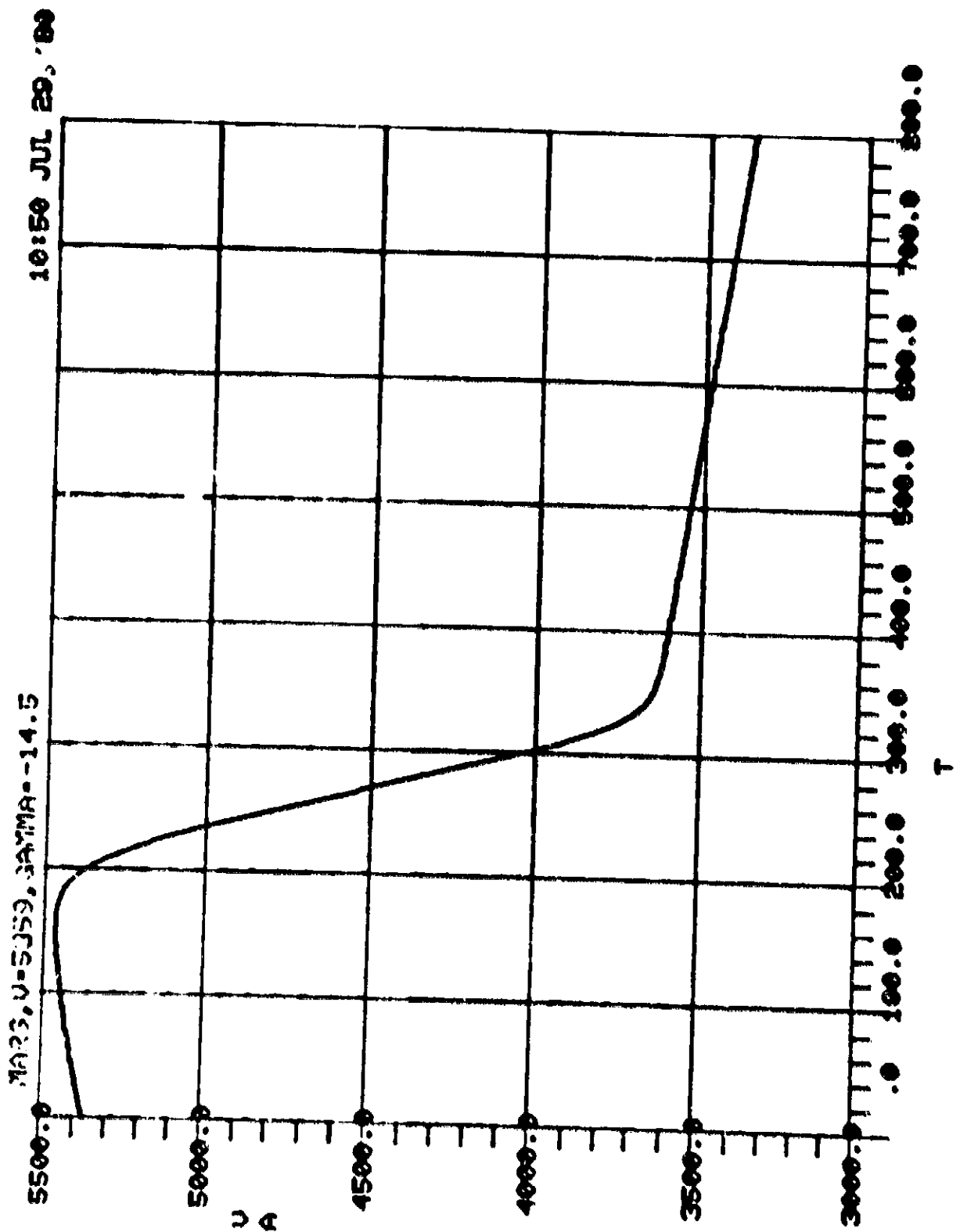
30.0

20.0



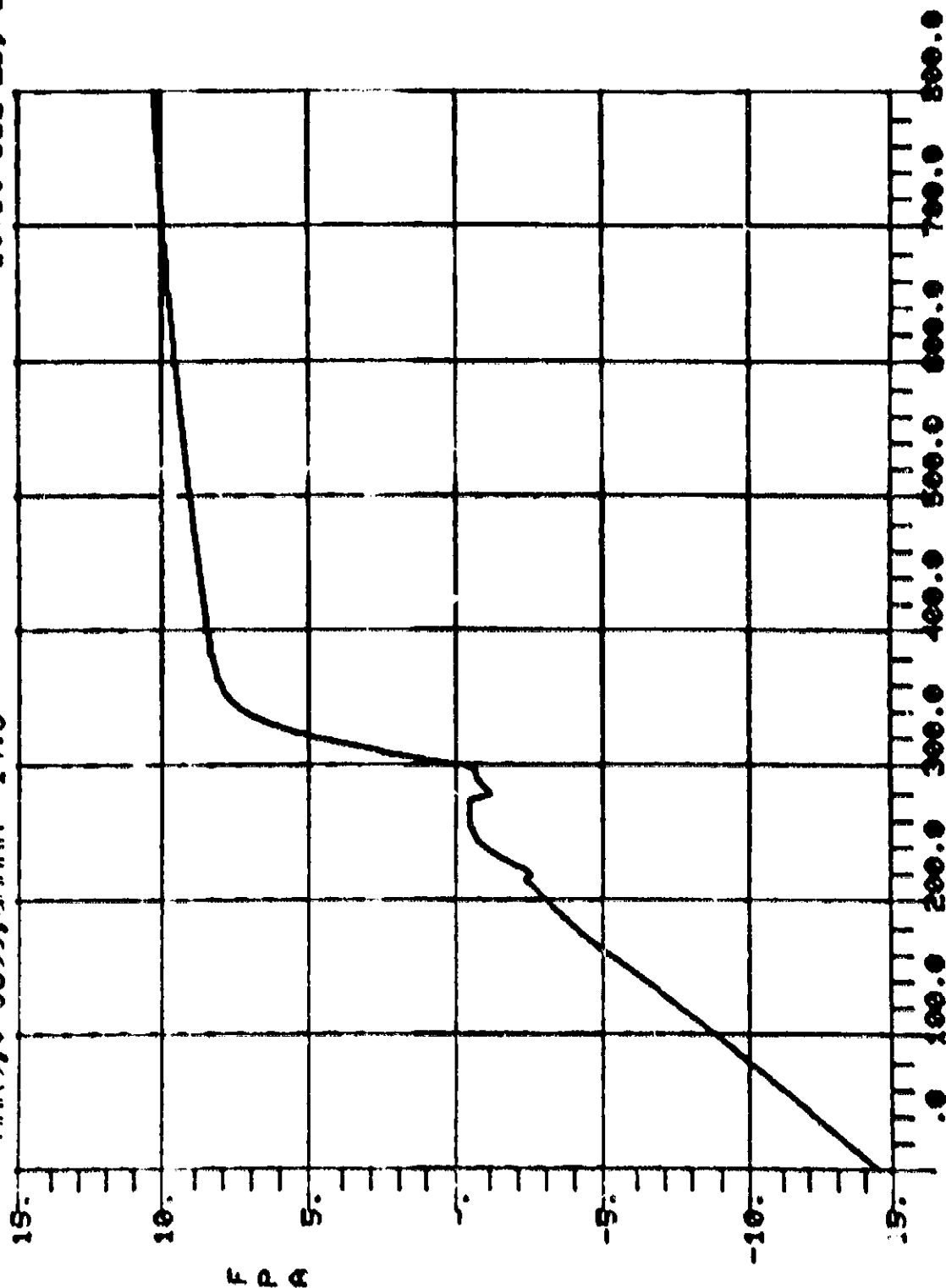
T

10:50 JUL 29, '80



10:50 JUL 29, '66

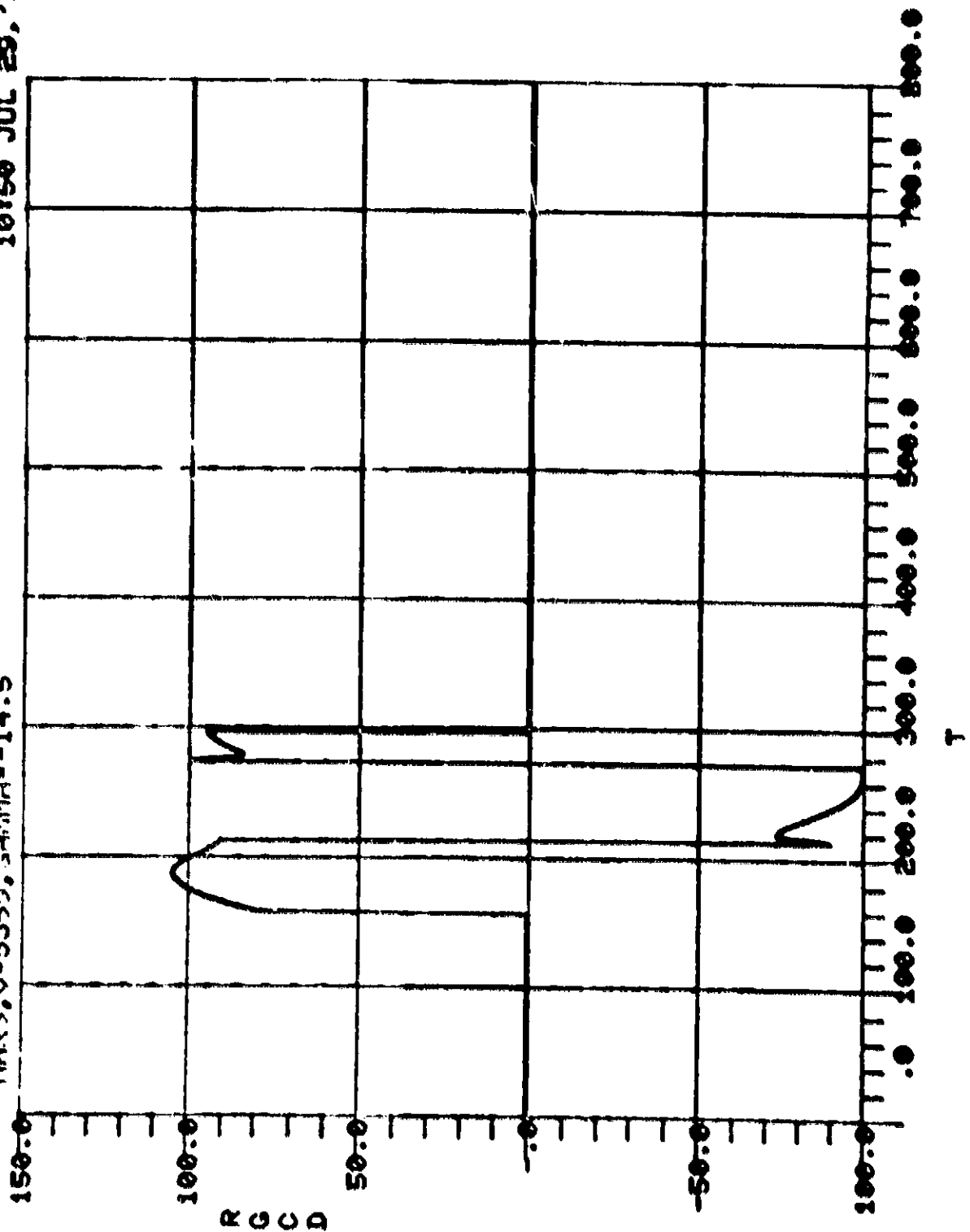
MARS, U=5353, GAMMA=-14.5



5110110

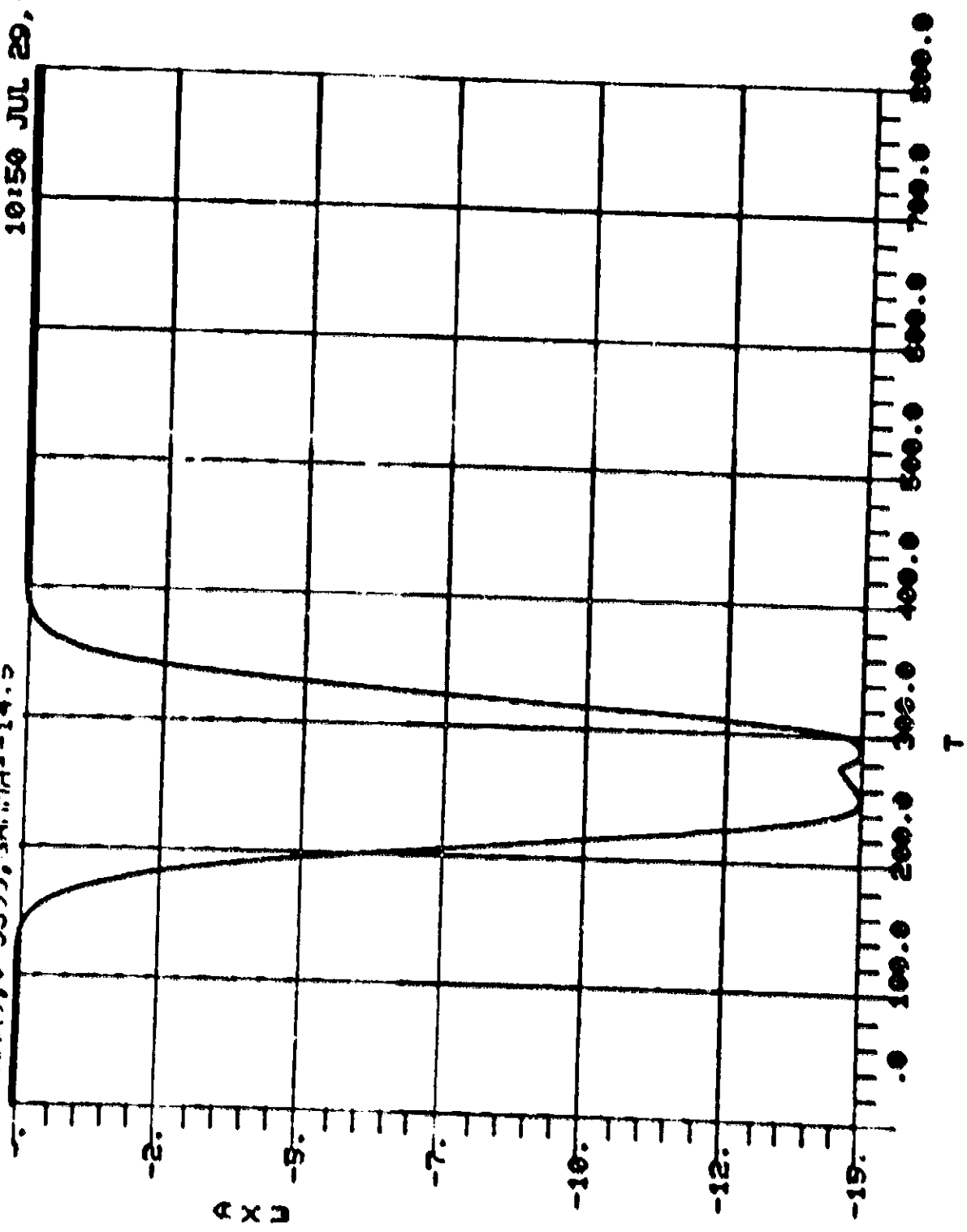
10:50 JUL 29, '80

MARS, U=5353, GAMMA=-14.5



1A23, U=5357, GAMMA=-14.5

10:50 JUL 29, '80



10:31 JUL 29, '80

MARS, U-5353, GAMMA--15.5

10 20.0

0 15.0

B

10.0

5.0

3000.0

3500.0

4000.0

4500.0

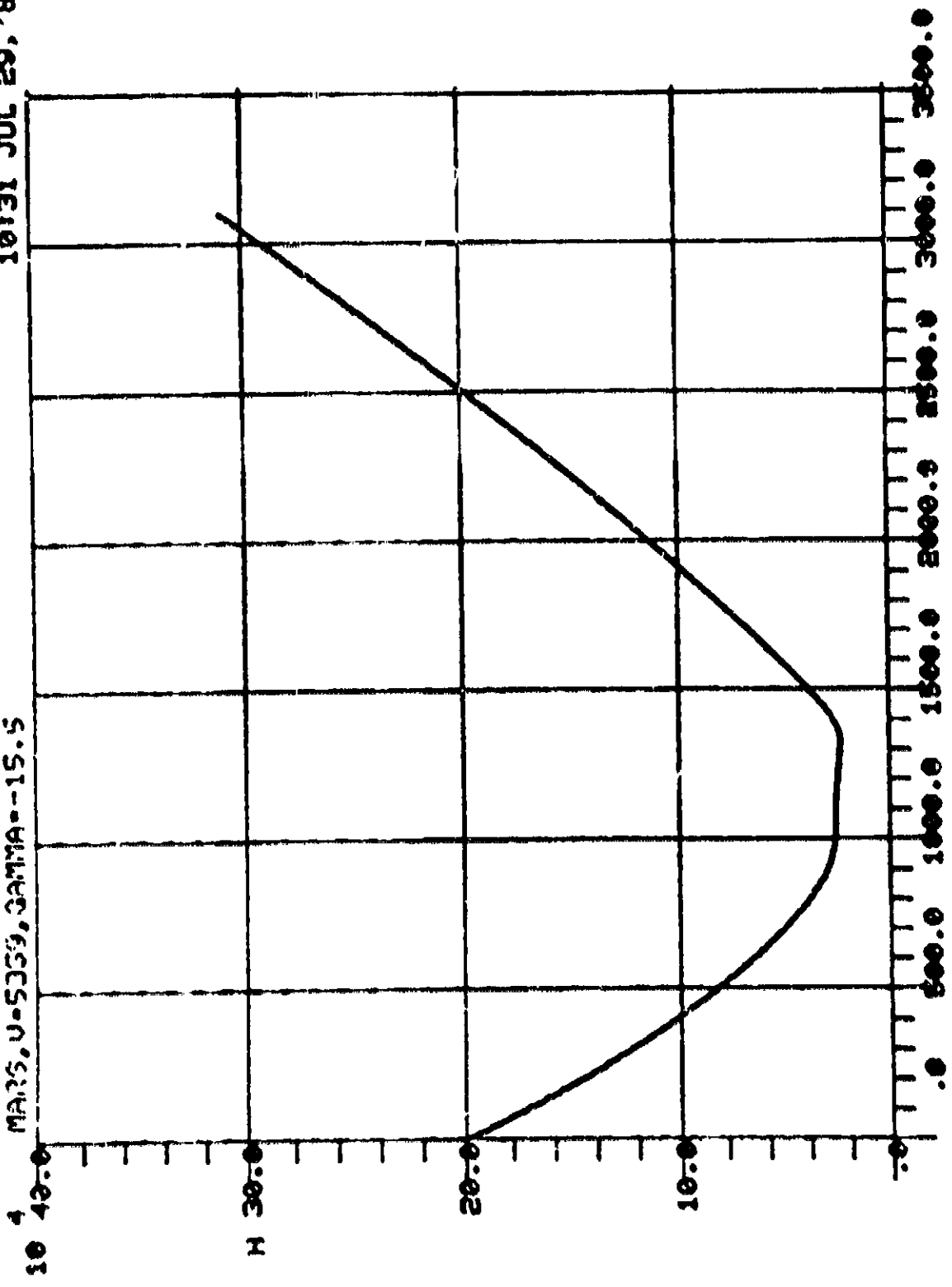
5000.0

5500.0

UA

10131 JUL 29, '80

MARS, U-535, GAMMA--15.5



DRND

FIGURE 7-1

10:31 JUL 29, '80

1A:15, U=5353, GAMMA=-15.5

10 43.0

H 30.0

20.0

10.0

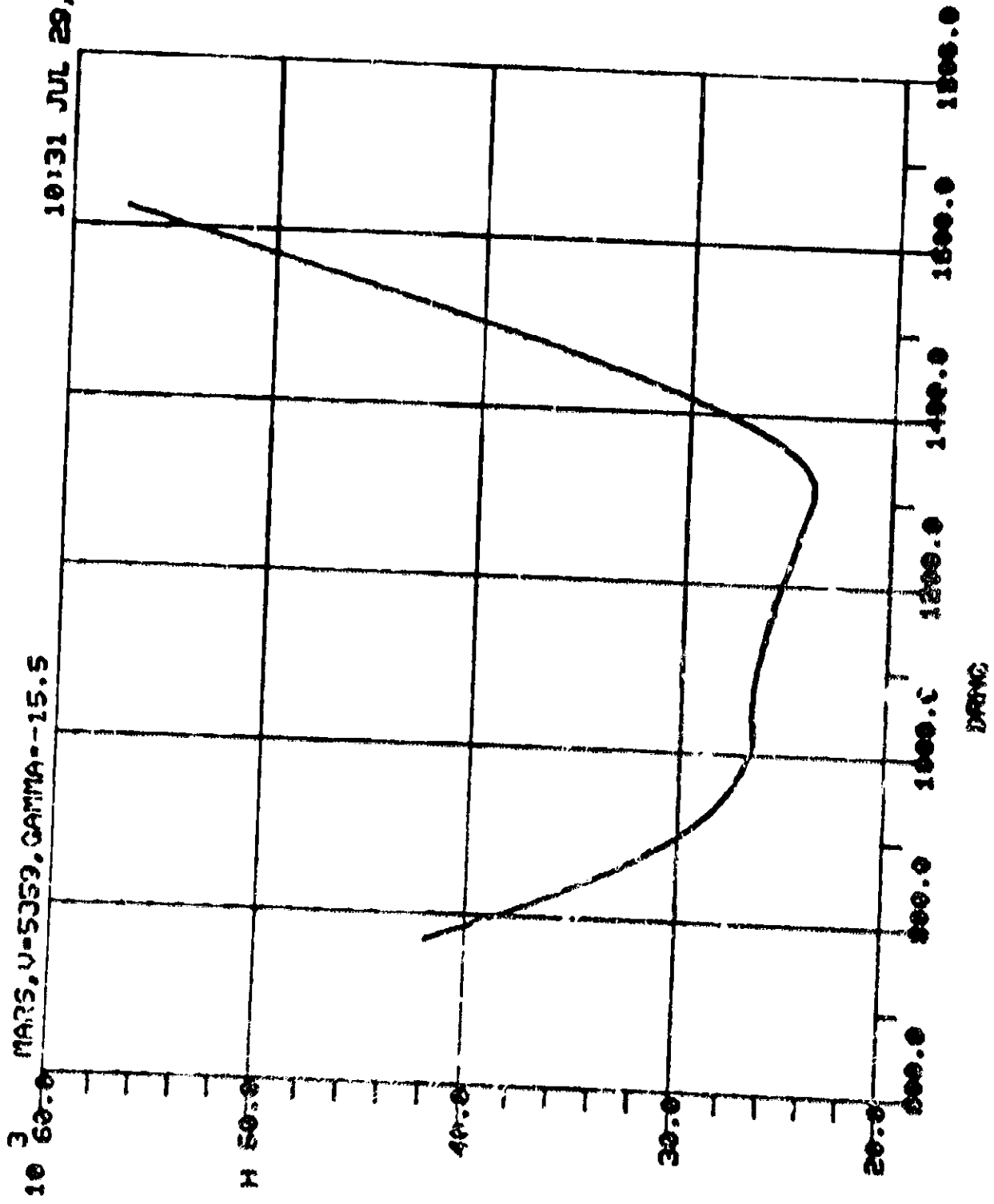
0.0 100.0 200.0 300.0 400.0 500.0 600.0 700.0 800.0

T

5.0325 1-1

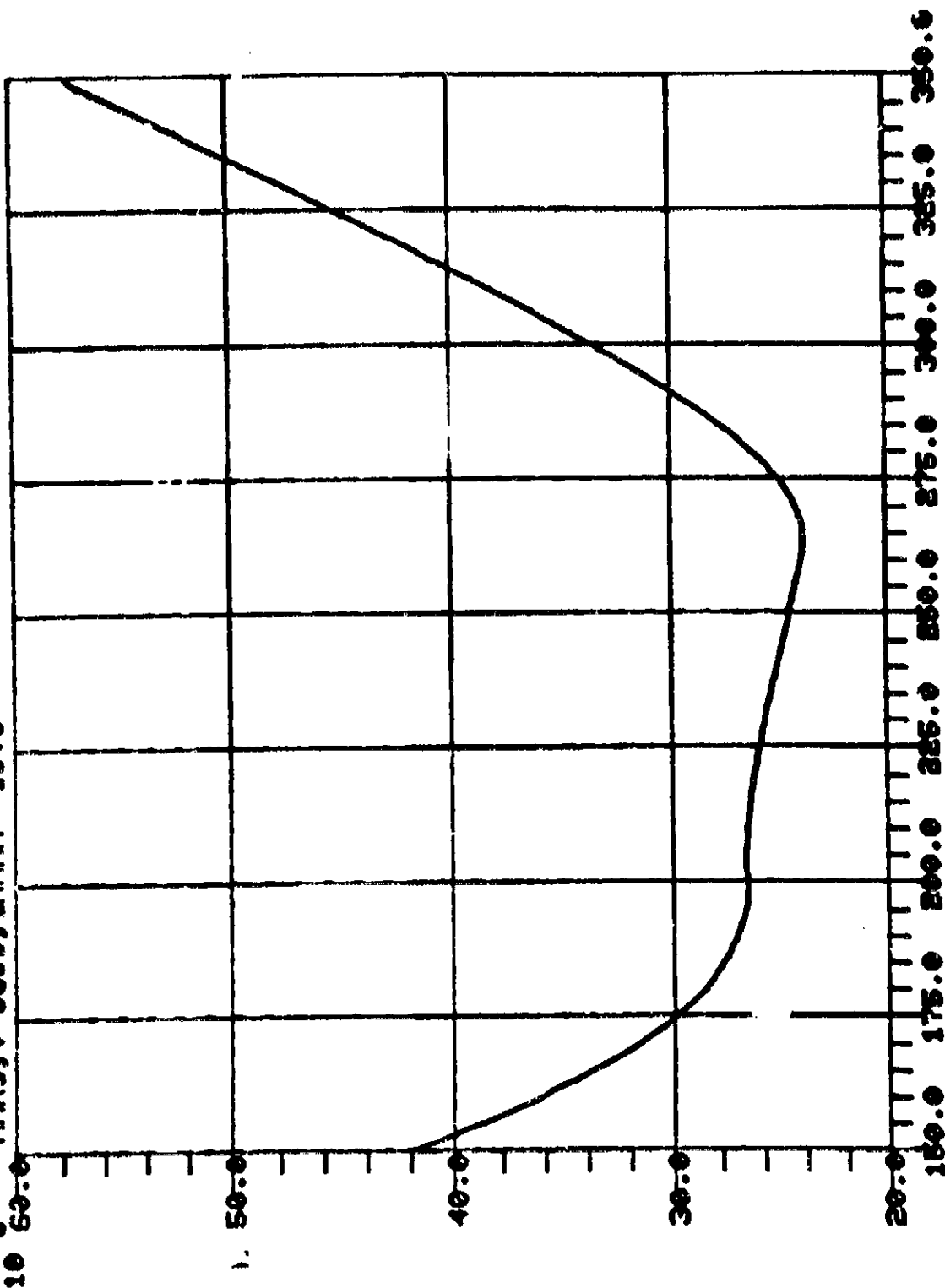
3 MARS, U=5359, GAMMA=-15.5

10:31 JUL 29, '80



10:31 JUL 29, '80

10 3 MAR3, V-5359, GAMMA--15.5



T

FIGURE B-14

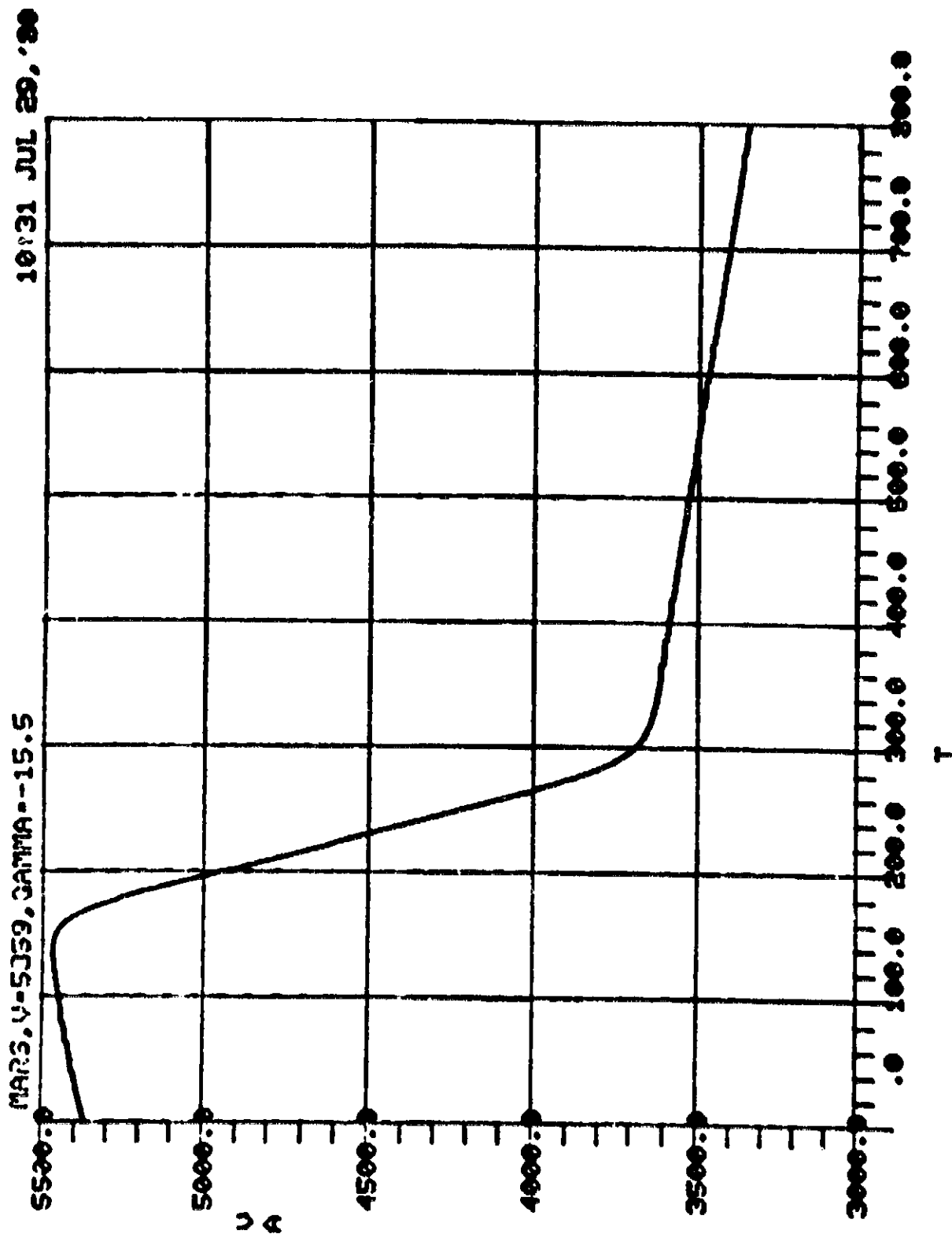
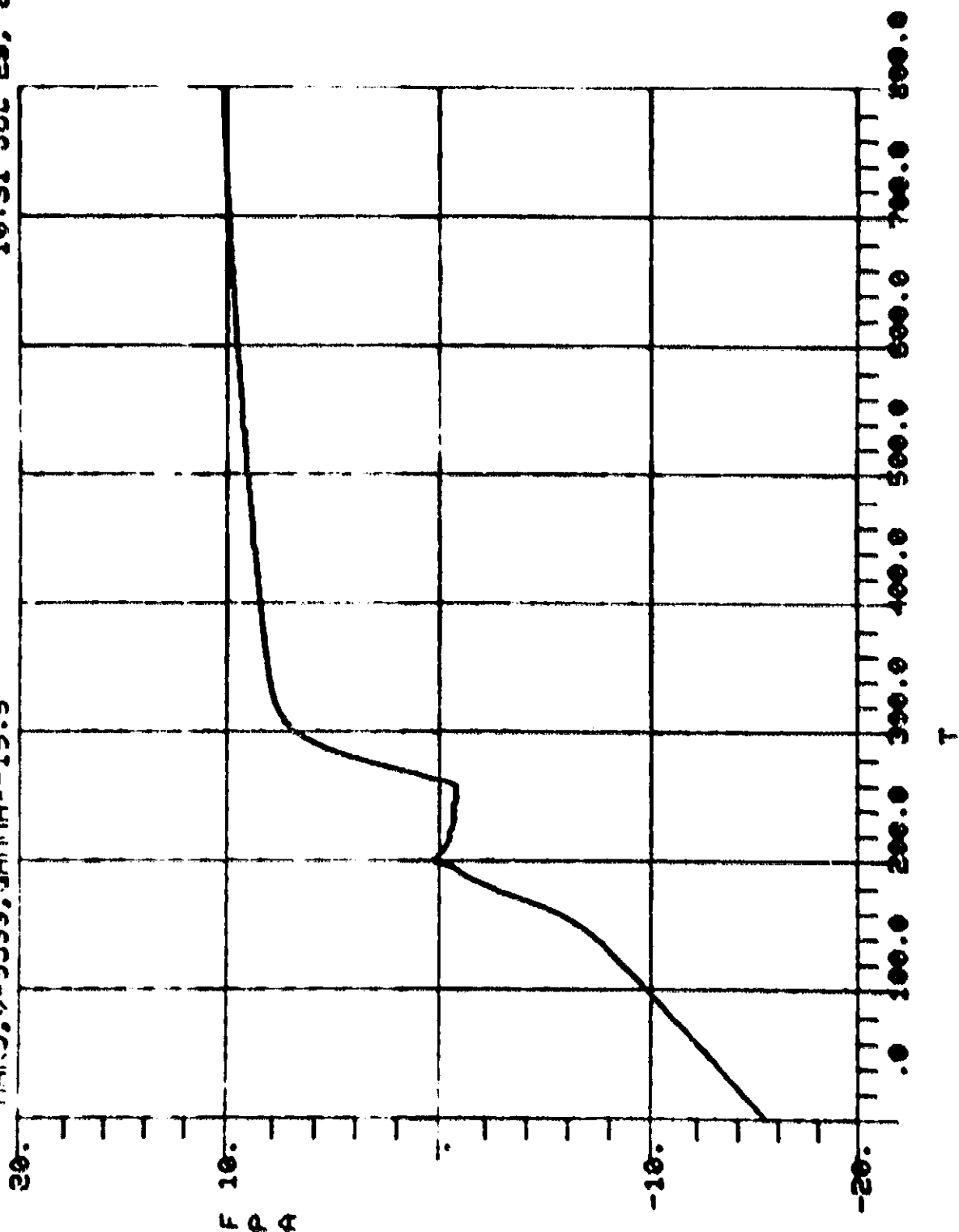


FIGURE 3.1

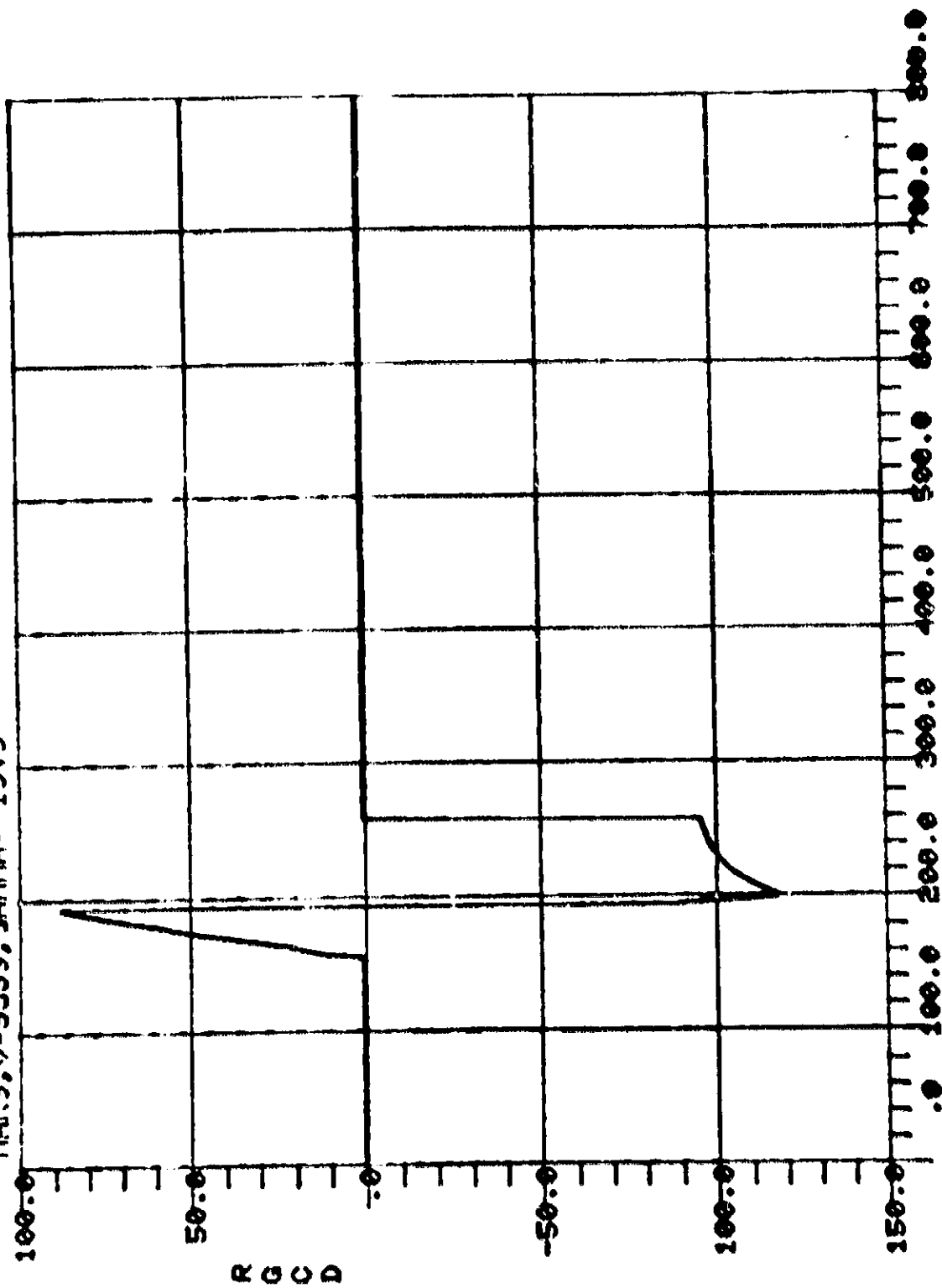
10:31 JUL 29, '80

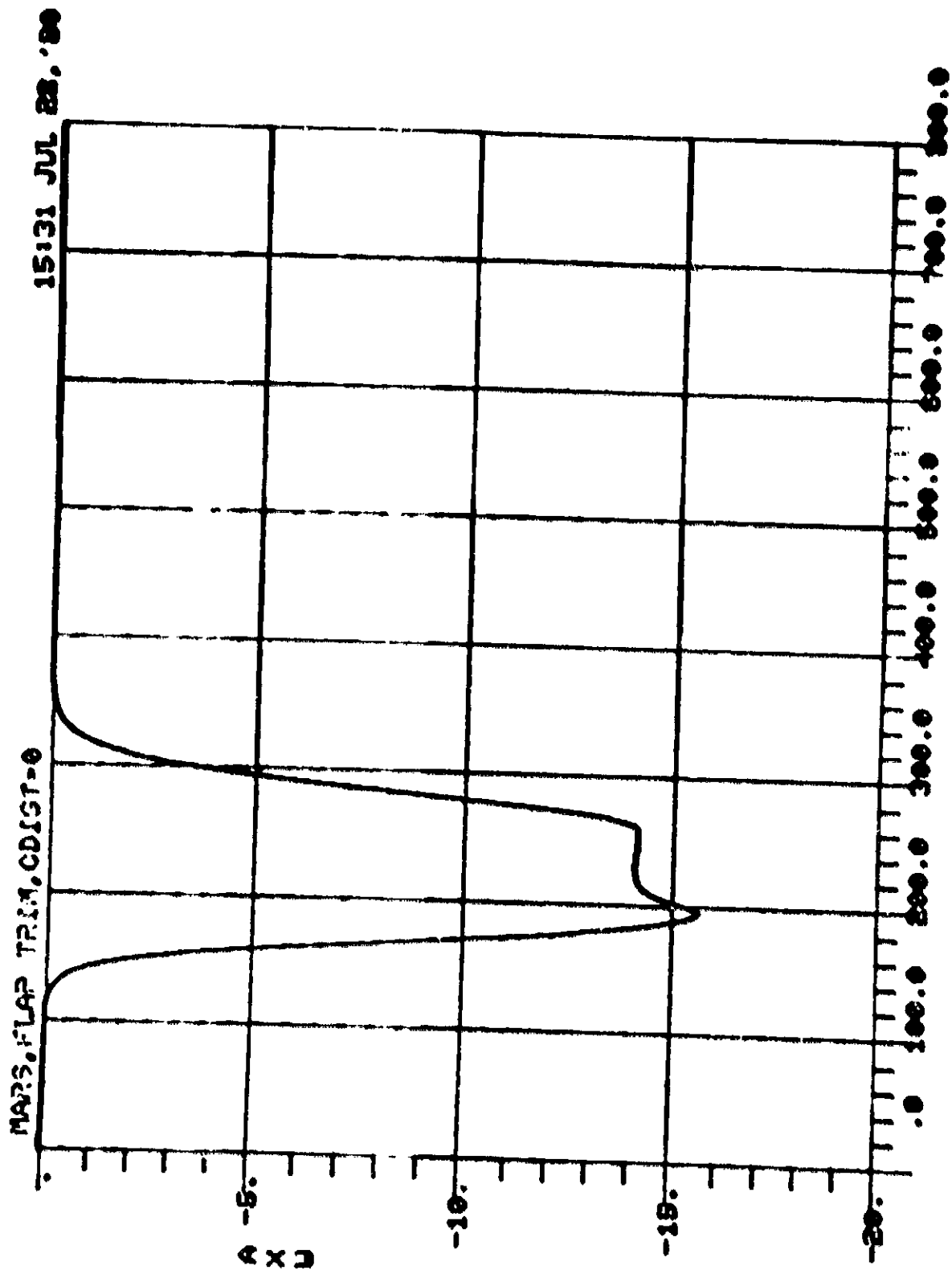
MAR3, V=5053, GAMMA=-15.5



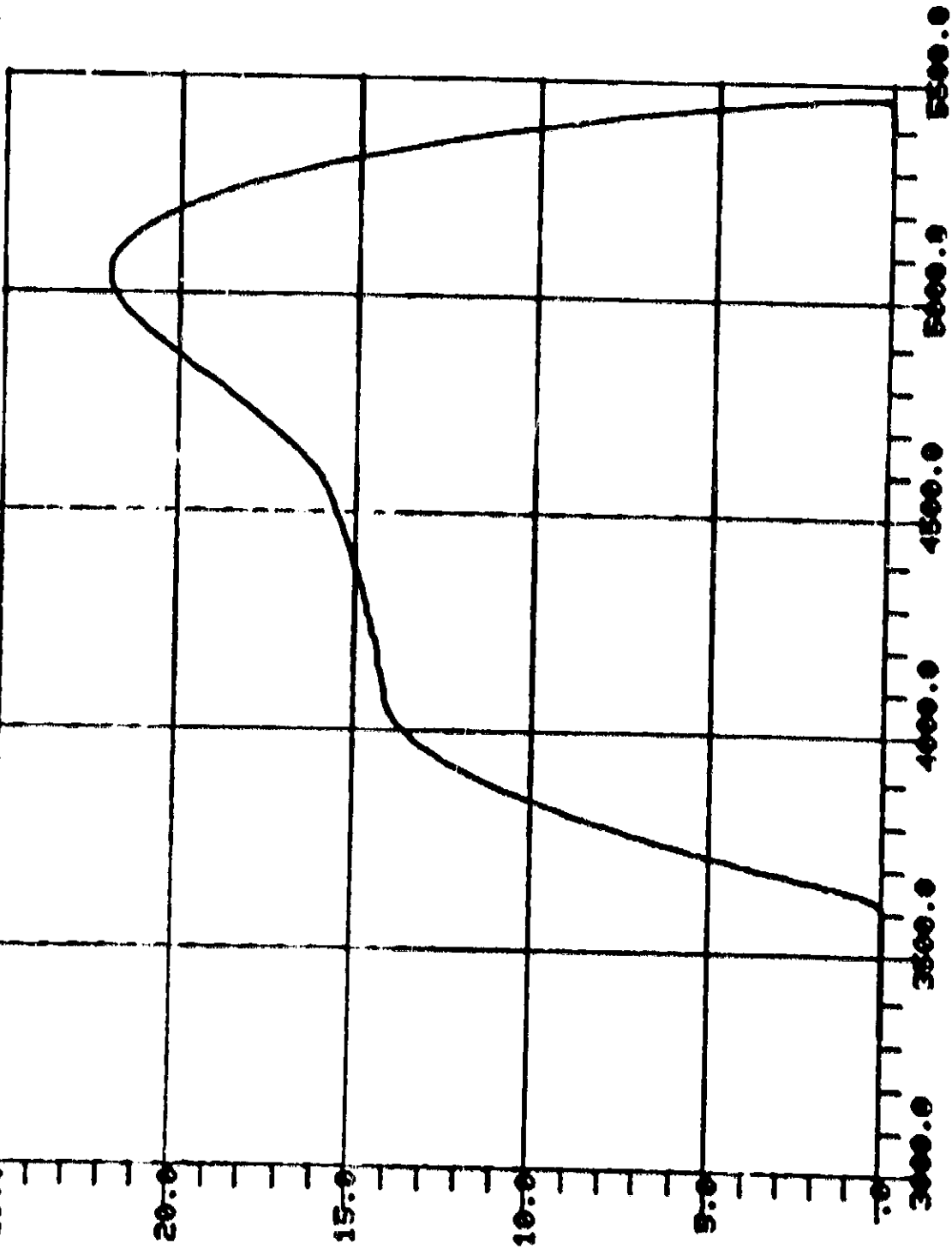
10:31 JUL 29, '80

MARS, U-5033, ZAMPA=-15.5





10 29.0 3 MARS, U=5353, GAMMA=-16.5 11:07 JUL 29, '80



UA

510 00 3-10

11:07 JUL 29, '80

MARS, U=5053, GAMMA=-16.5

10 40.0

H 30.0

20.0

10.0

0.0

0.0 500.0 1000.0 1500.0 2000.0 2500.0 3000.0 3500.0

DPMO

11:07 JUL 29, '80

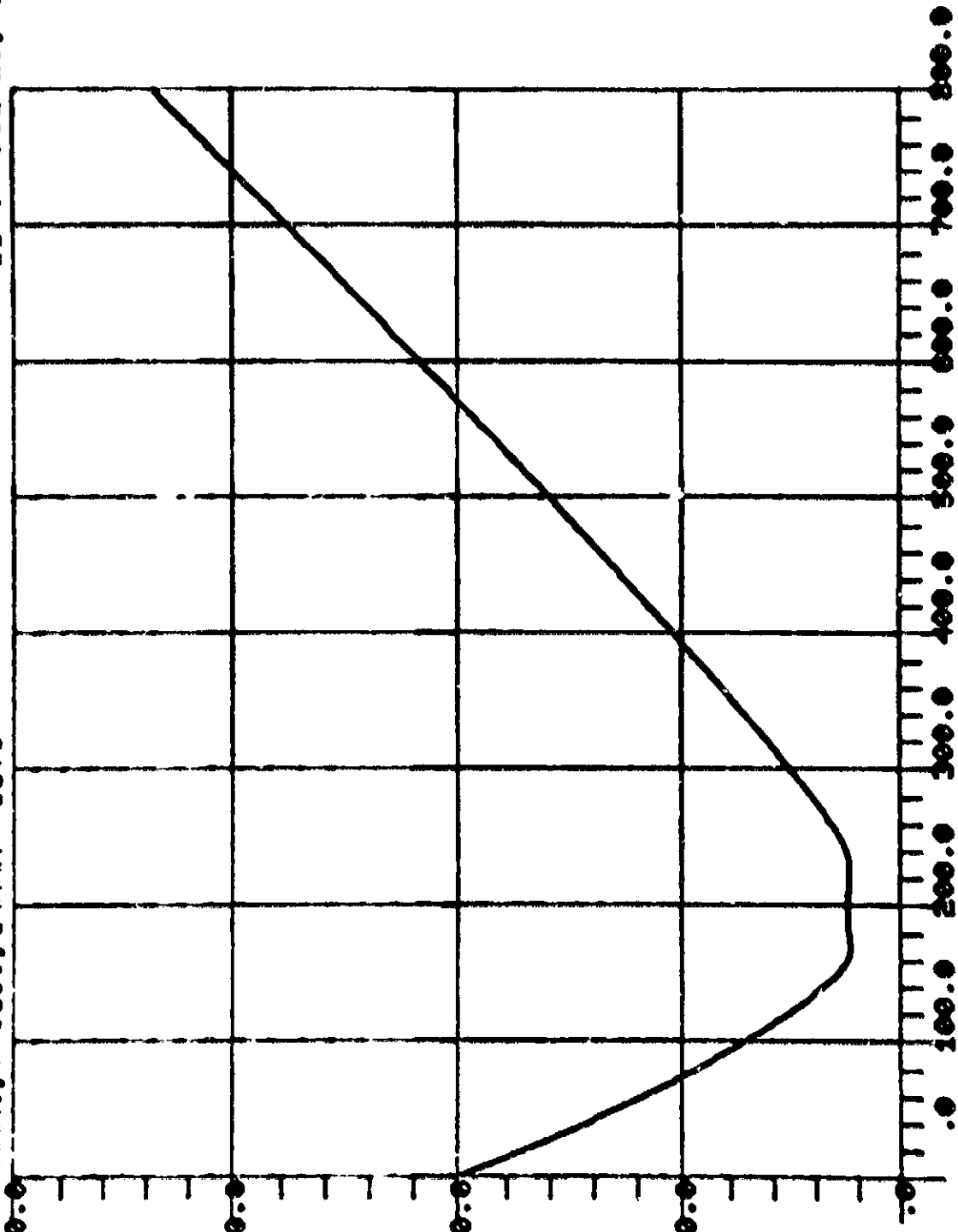
MARS, U=5353, GAMMA=-16.5

10 40.0

H 30.0

20.0

10.0



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7.019E 8-21

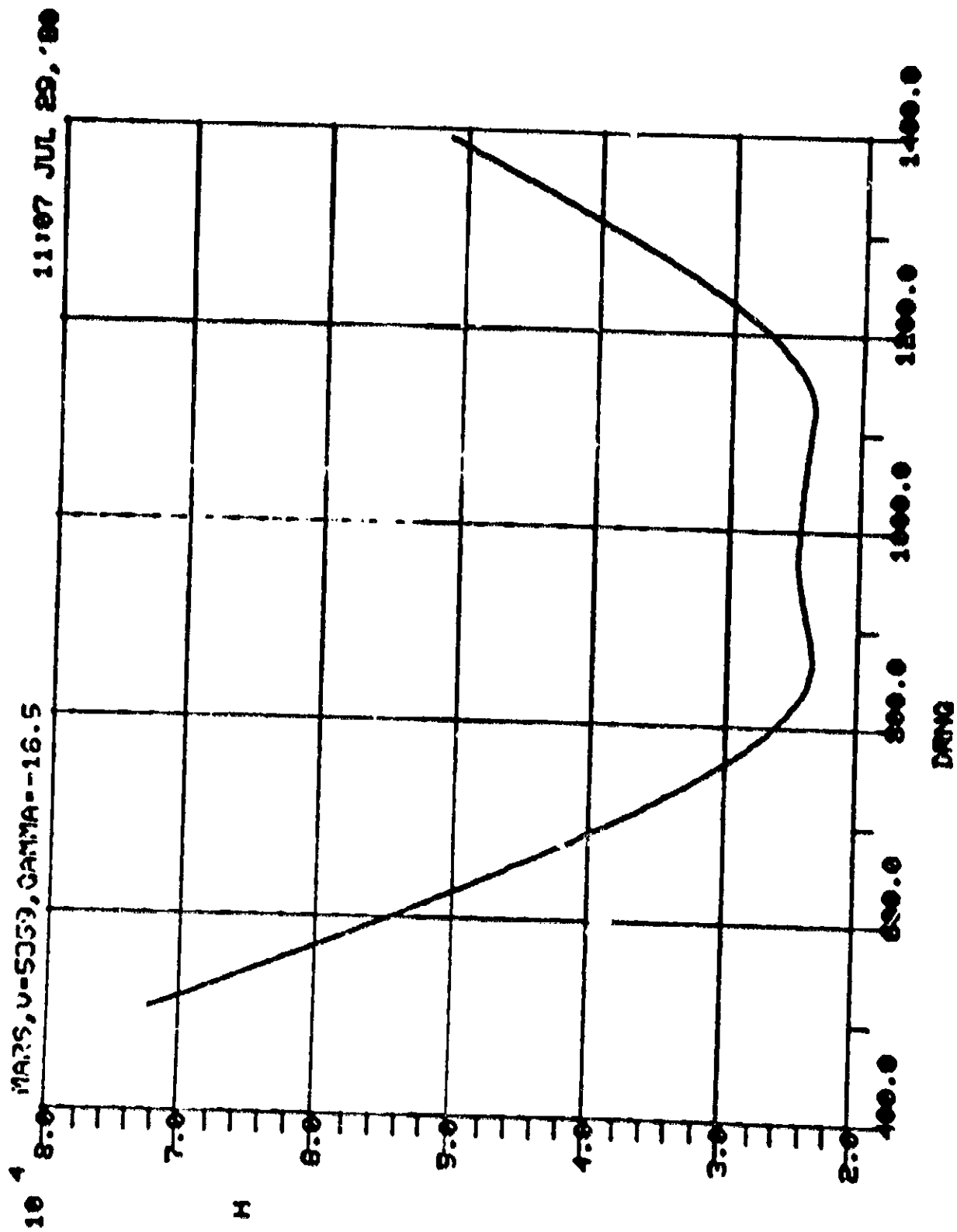
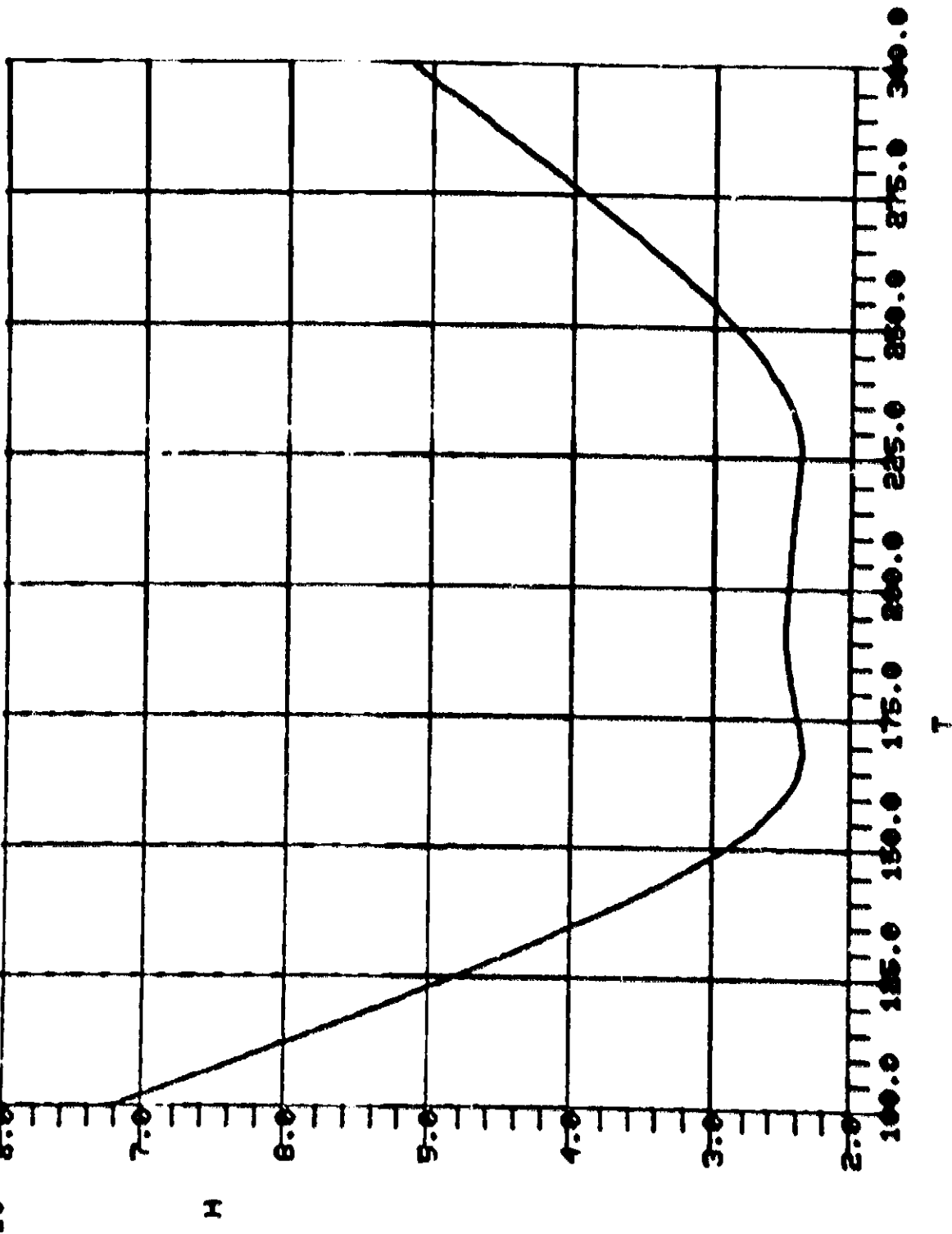


FIGURE 2-10

11107 JUL 29, '80

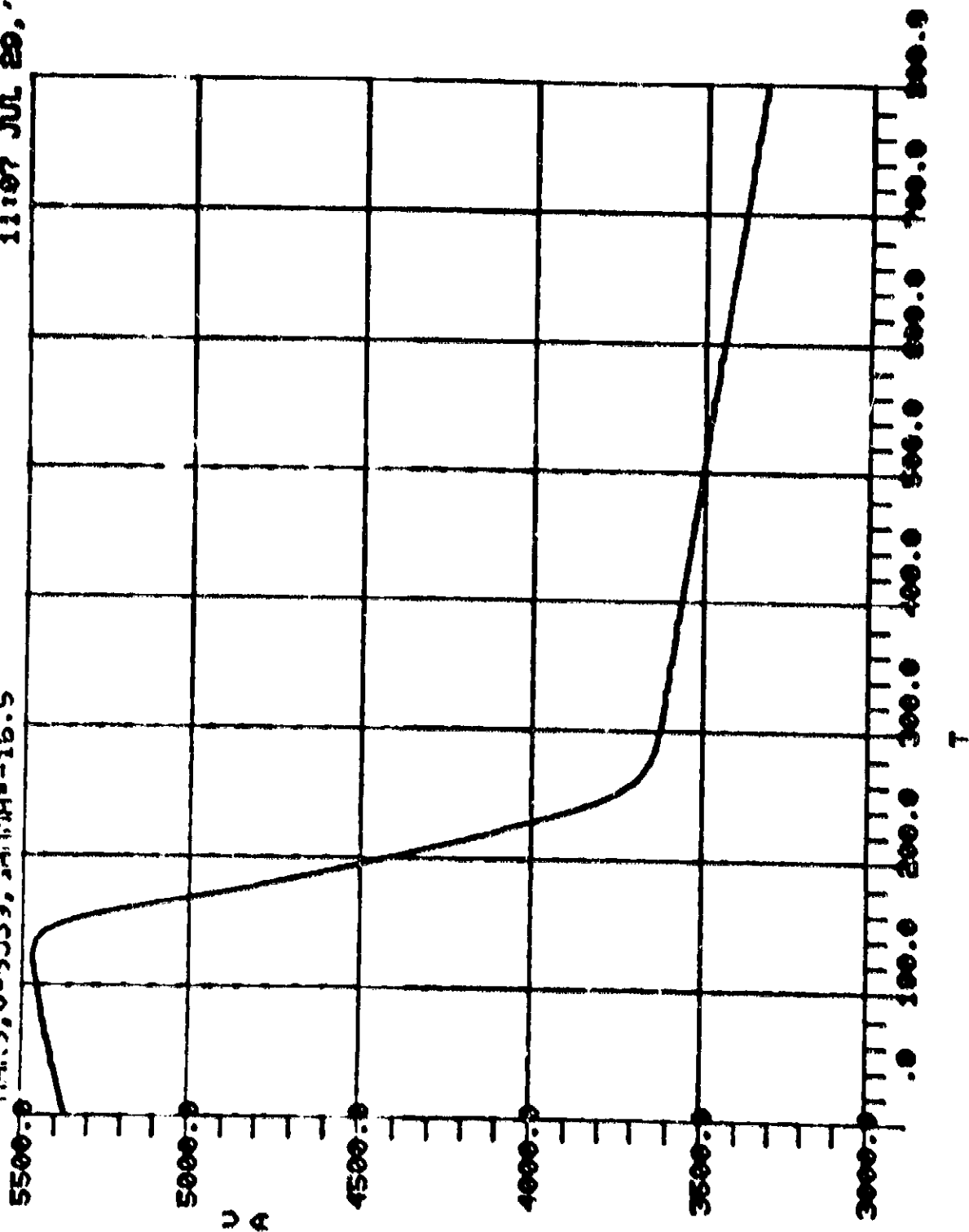
10⁴ MARS, U=5039, GAMMA=-15.5



210312-0

11:07 JUL 29, '80

MARS, U-5359, 3A7MA--16.5



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MARS, U-5353, GAMMA--16.5

11:07 JUL 29, '80

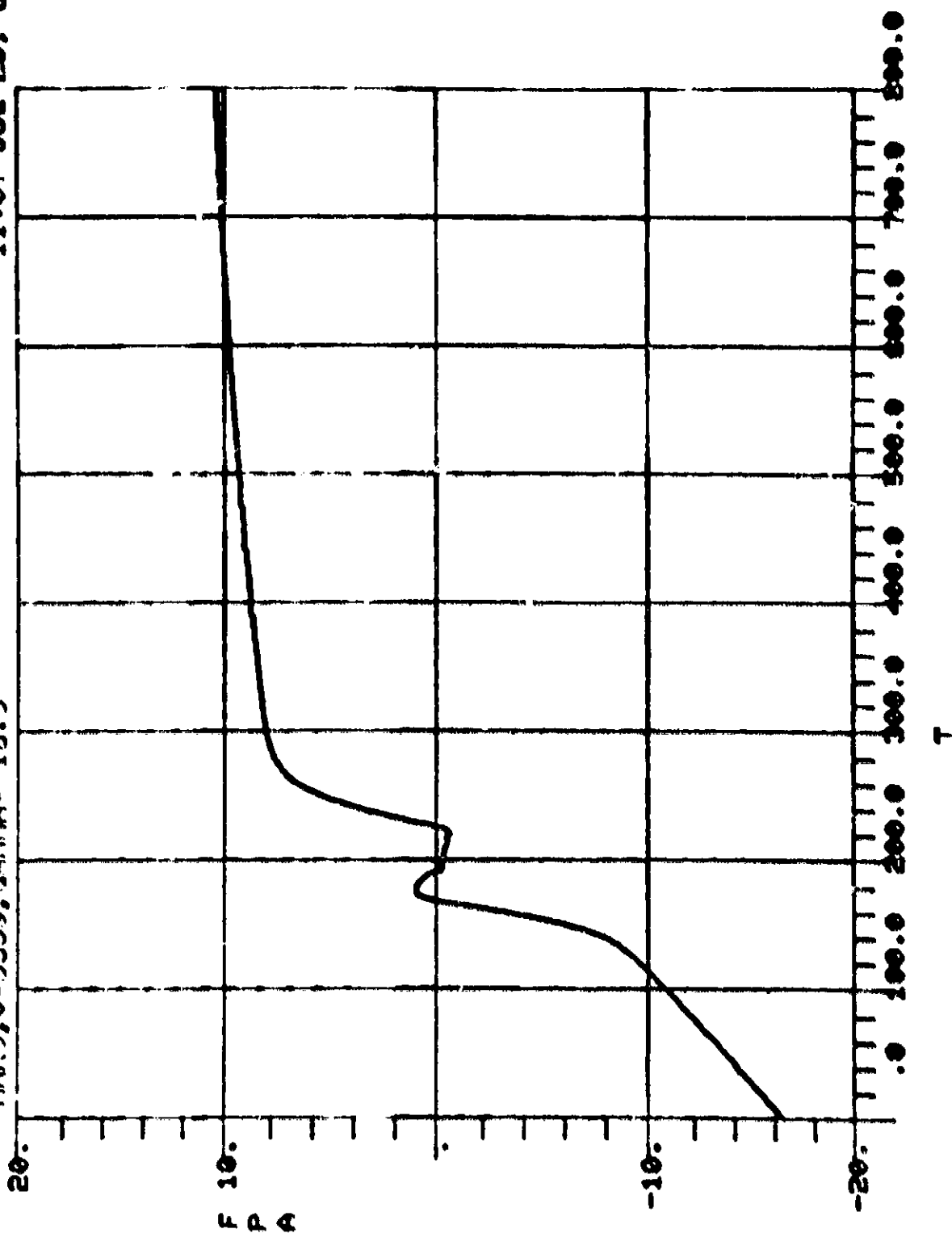
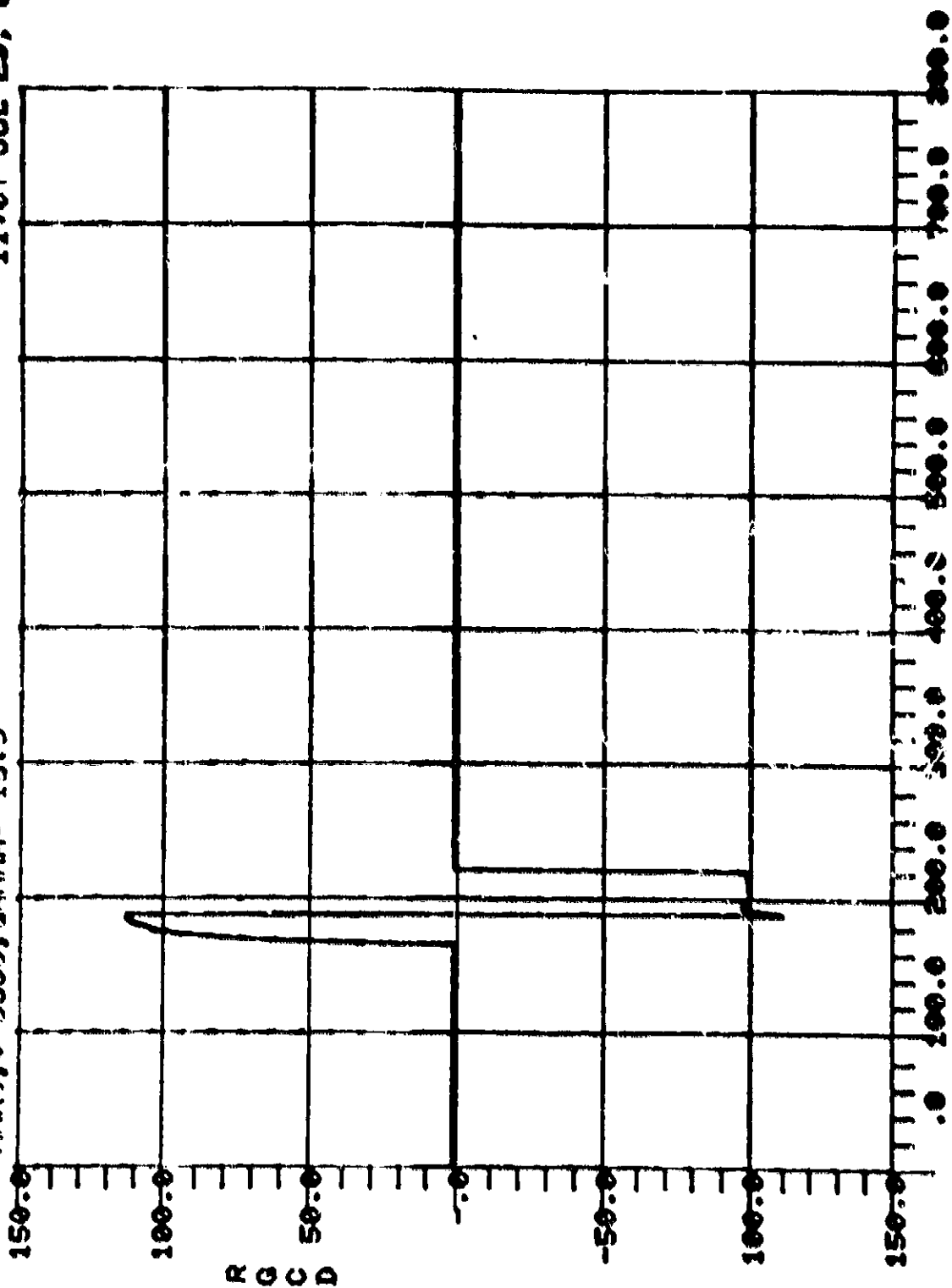


FIGURE 3-13

MARS, U-5353, GAMMA--13.5

11:07 JUL 29, '88



11:07 JUL 29, '80

MARS, U-5053, GAMMA-13.5

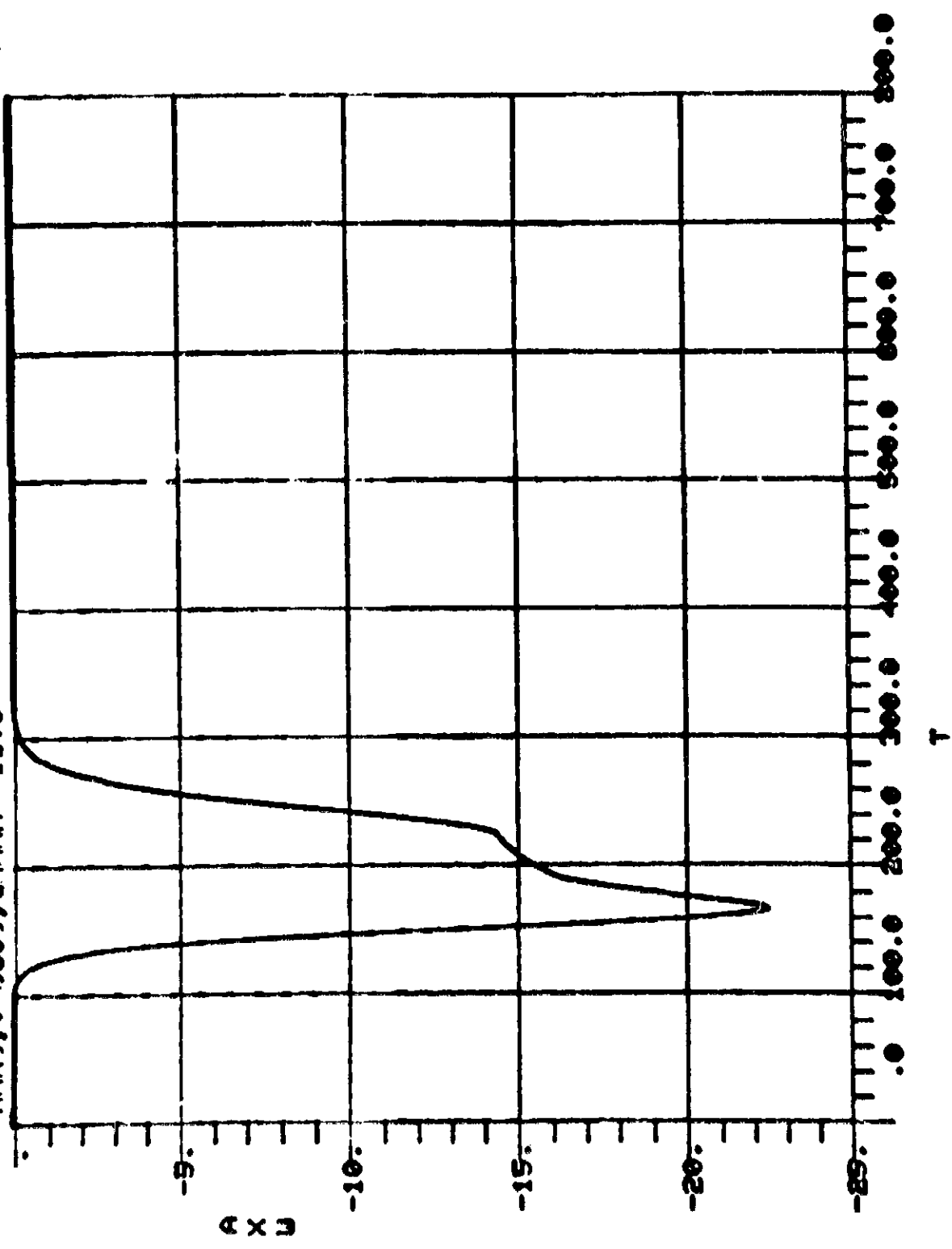


FIGURE 2-1

APPENDIX C

URANUS TRAJECTORIES

The following Uranus atmospheric entry trajectories are included in this Appendix:

<u>Entry Velocity</u> (m/sec)	<u>Flight Path Angle</u> (degrees)	<u>Reference Drag,</u> <u>D_{REF} in earth g's</u>	<u>Figures</u>
30,000	- 8.0	20	C1 through C8
30,000	-10.0	20	C9 through C16
30,000	-12.0	20	C17 through C24
30,000	- 8.0	15	C25 through C32
30,000	-10.0	15	C33 through C40
30,000	-12.0	15	C41 through C48

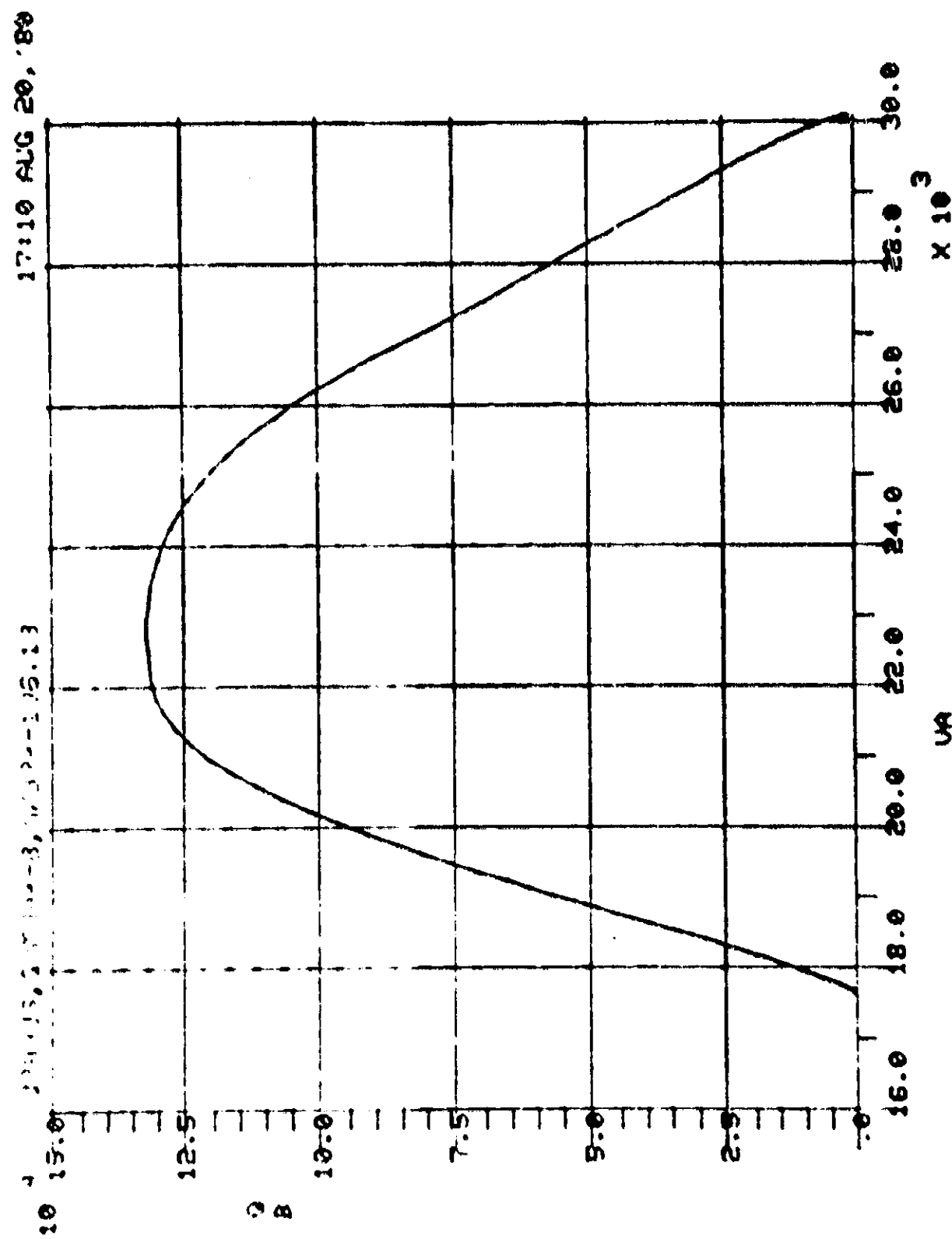


FIGURE 3-1

17:10 AUG 20, '80

201015, 201015-3, 201015-195.13

10 2:0

H 5:0

4:0

3:0

2:0

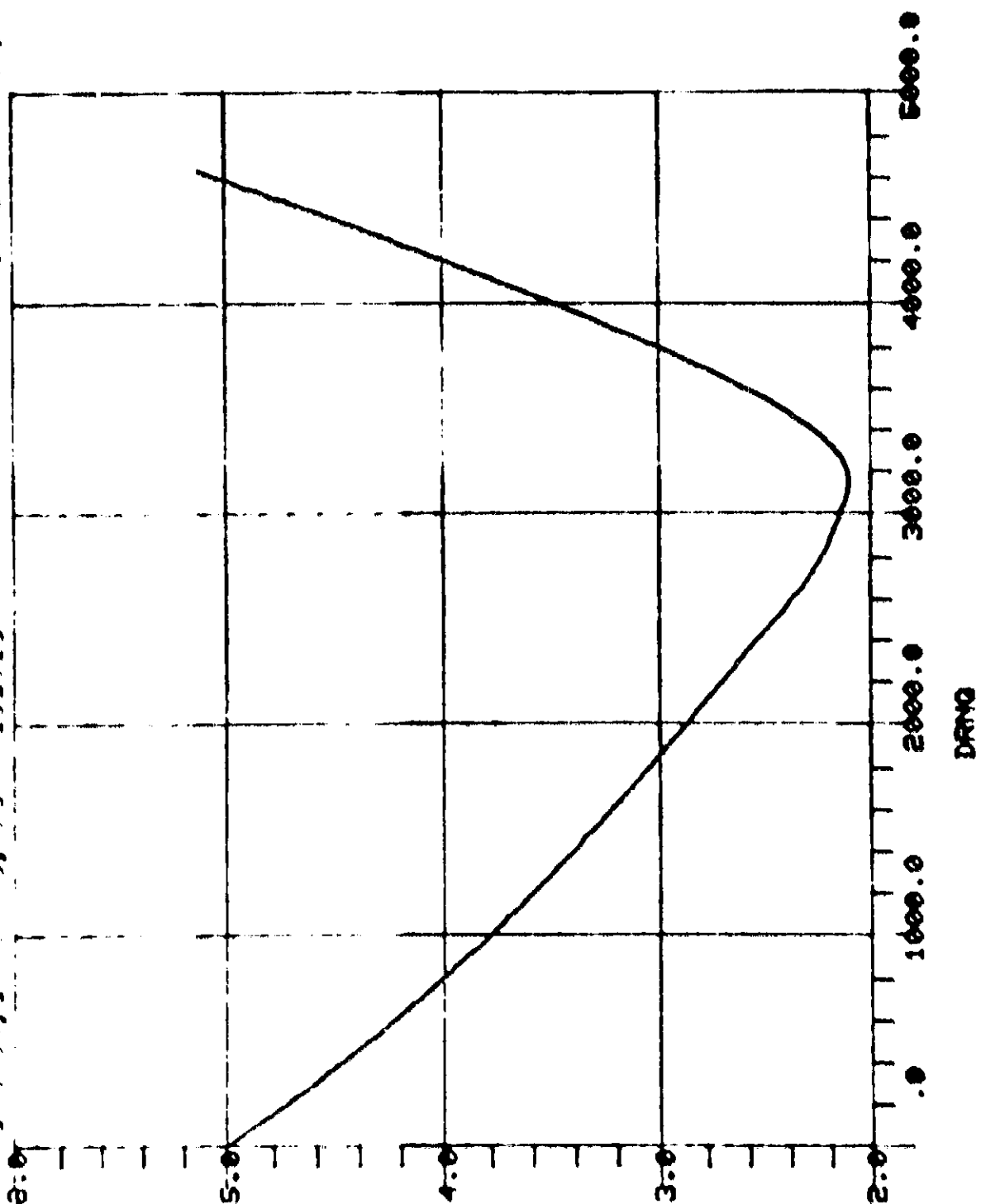


FIGURE C-2

17110 AUG 20, '80

324913, 2, 6, 14, 20, 3, 5, 13, 20, 1, 15, 13

10 8.0

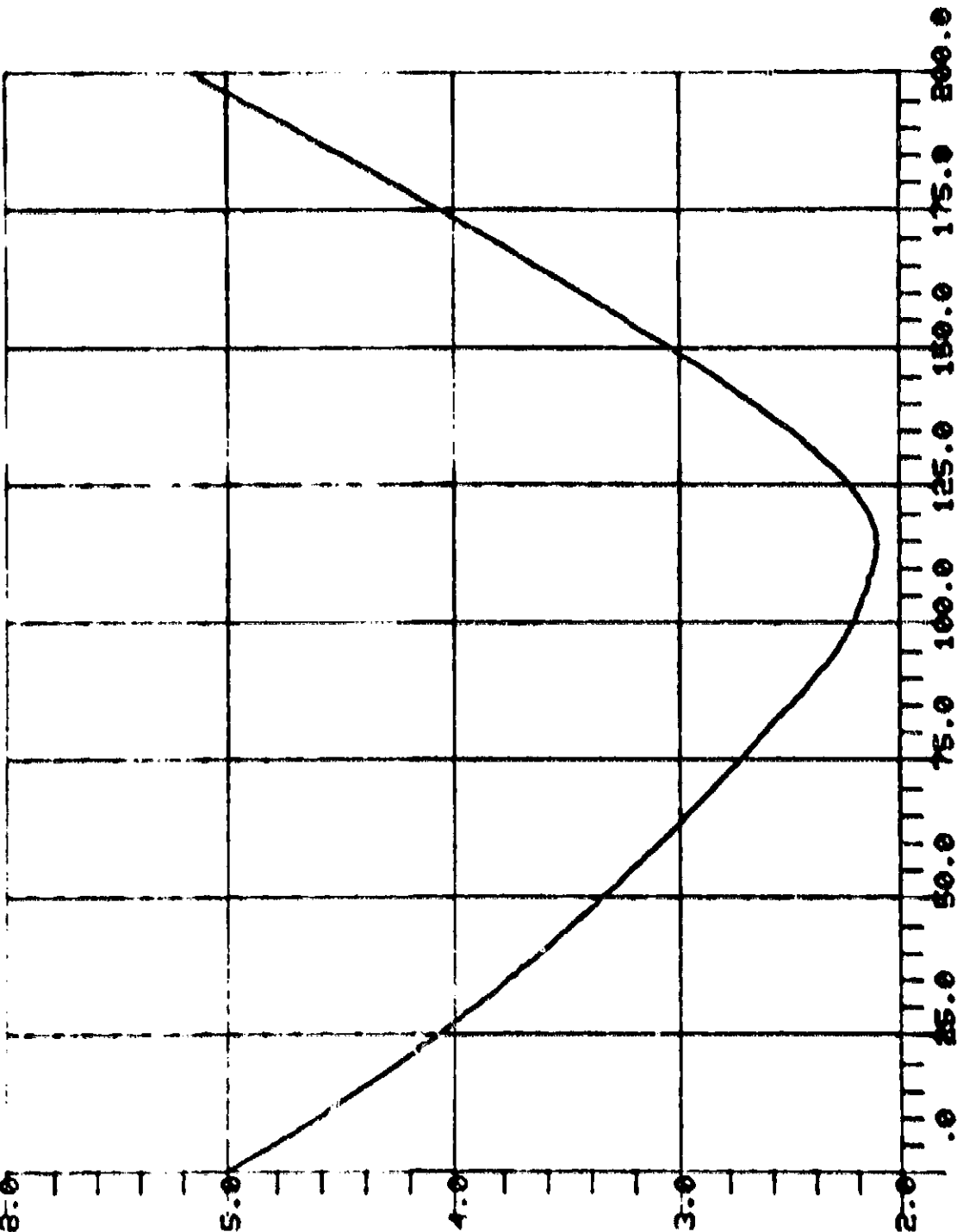
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4.0

3.0

2.0

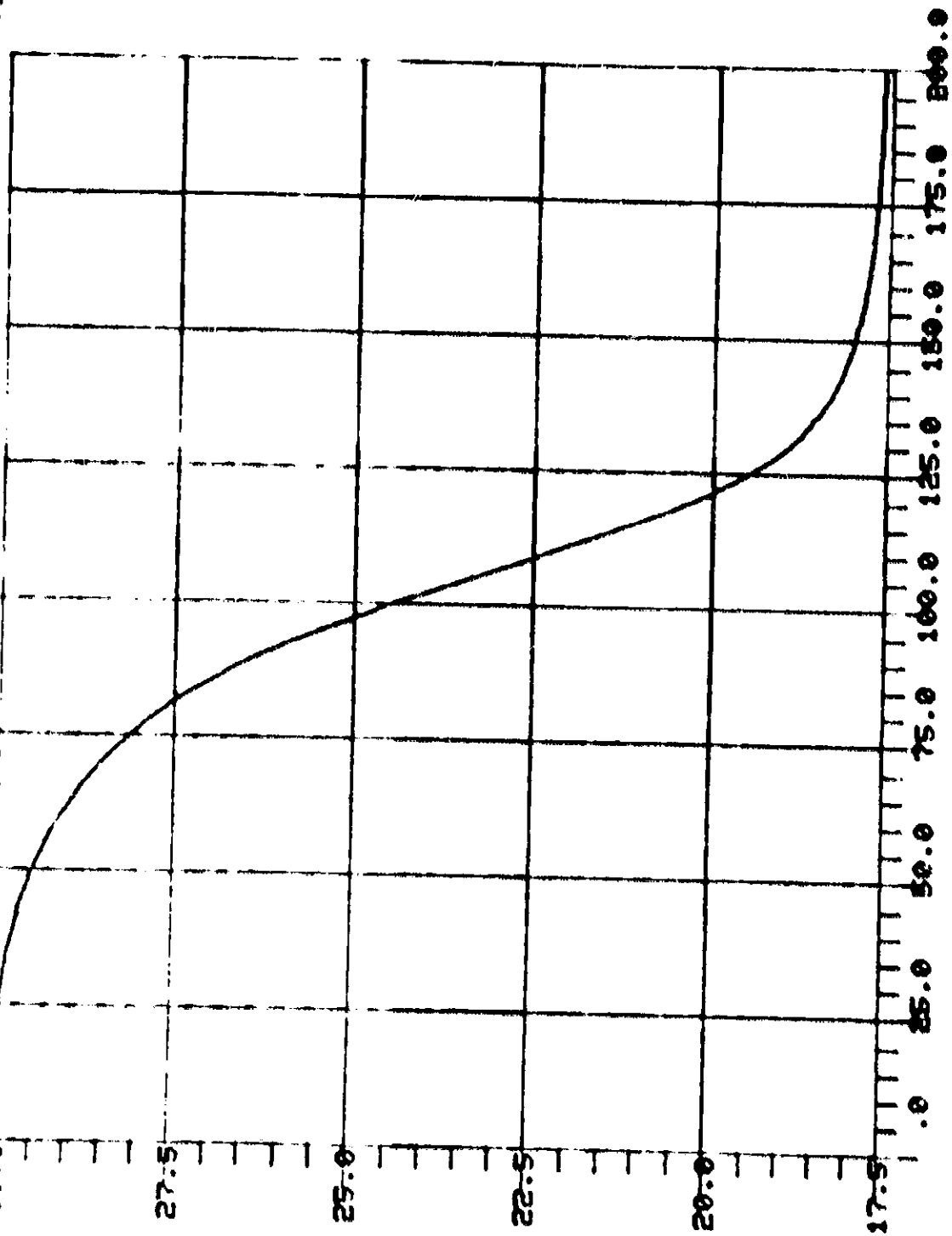


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FIGURE 1-3

17:10 AUG 20, '80

10 32.0 24.13, 2.07 -3, 12.13-1.15.13

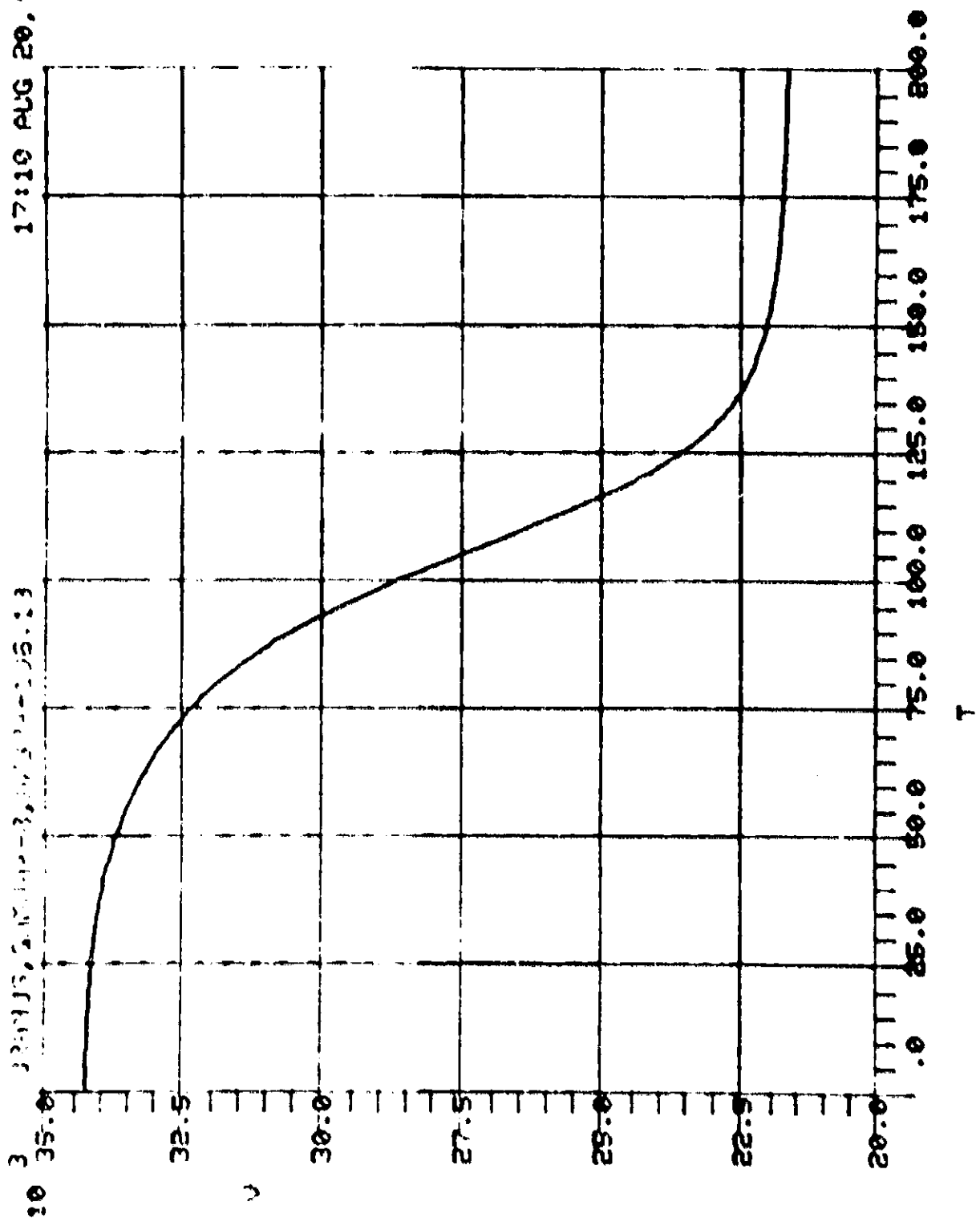


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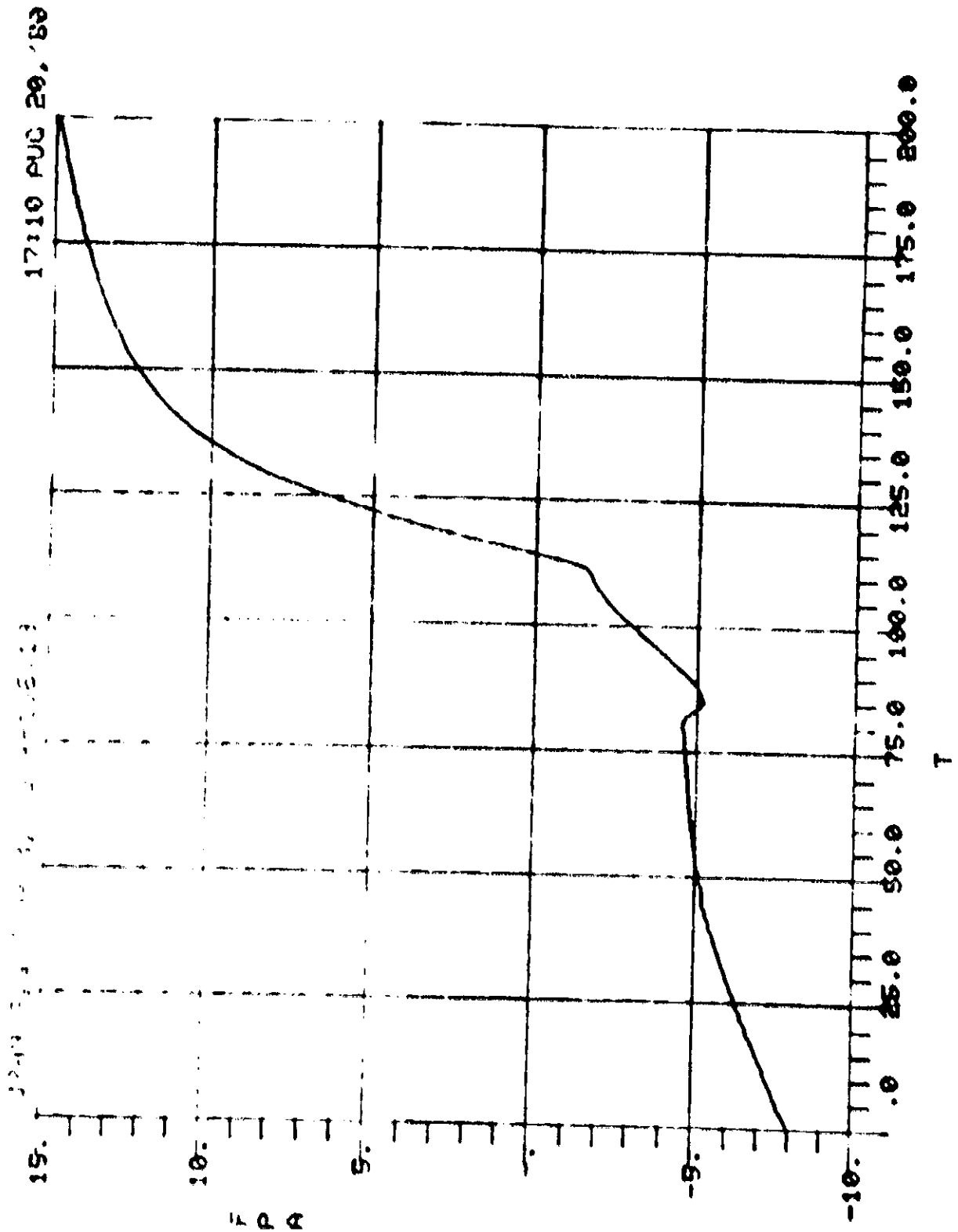
FIGURE 1-1

17:10 AUG 20, '80

320115, 200115-3, 00131-205.13



200115-3



17:19 AUG 20, 80

10-3, 105-105.13

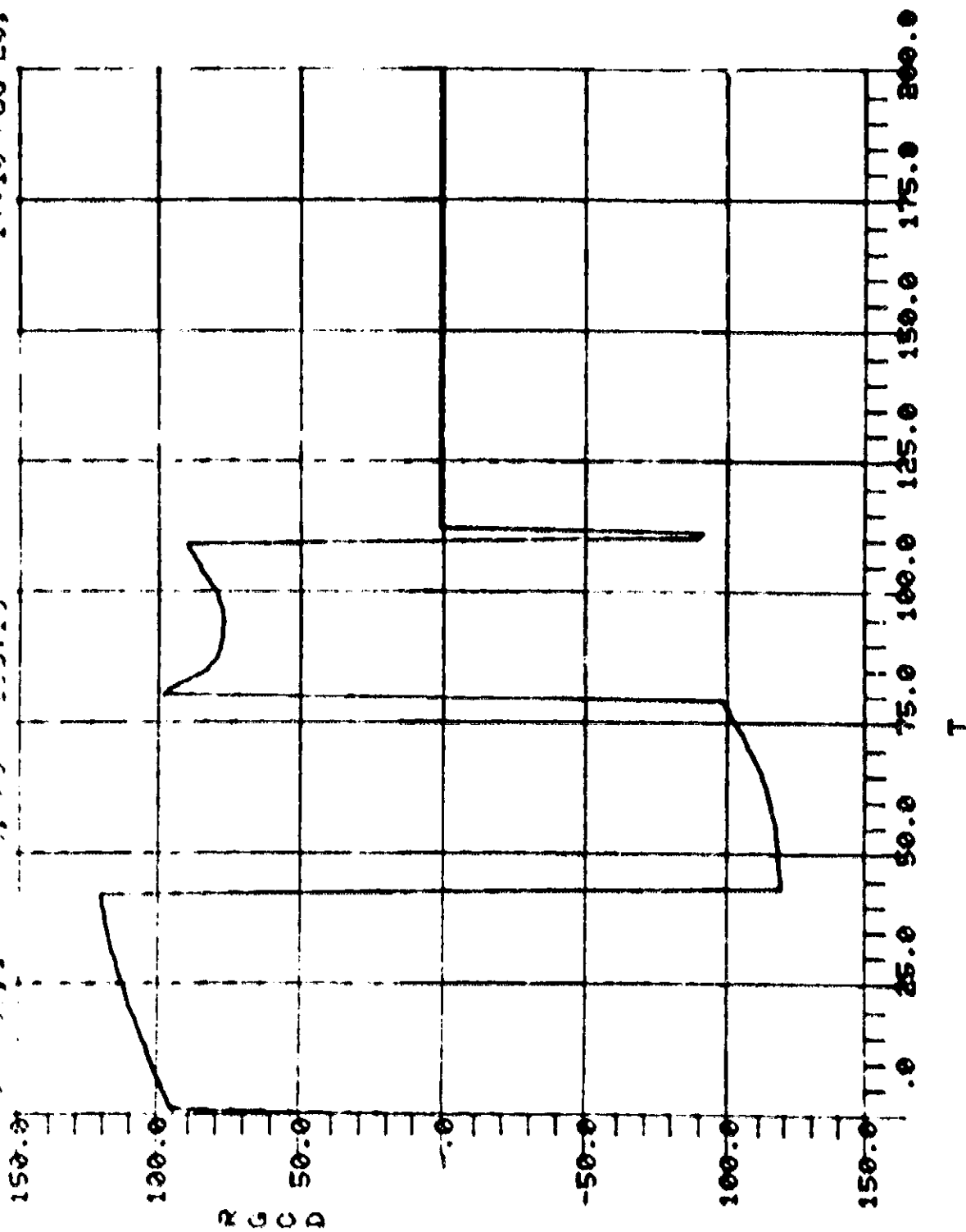
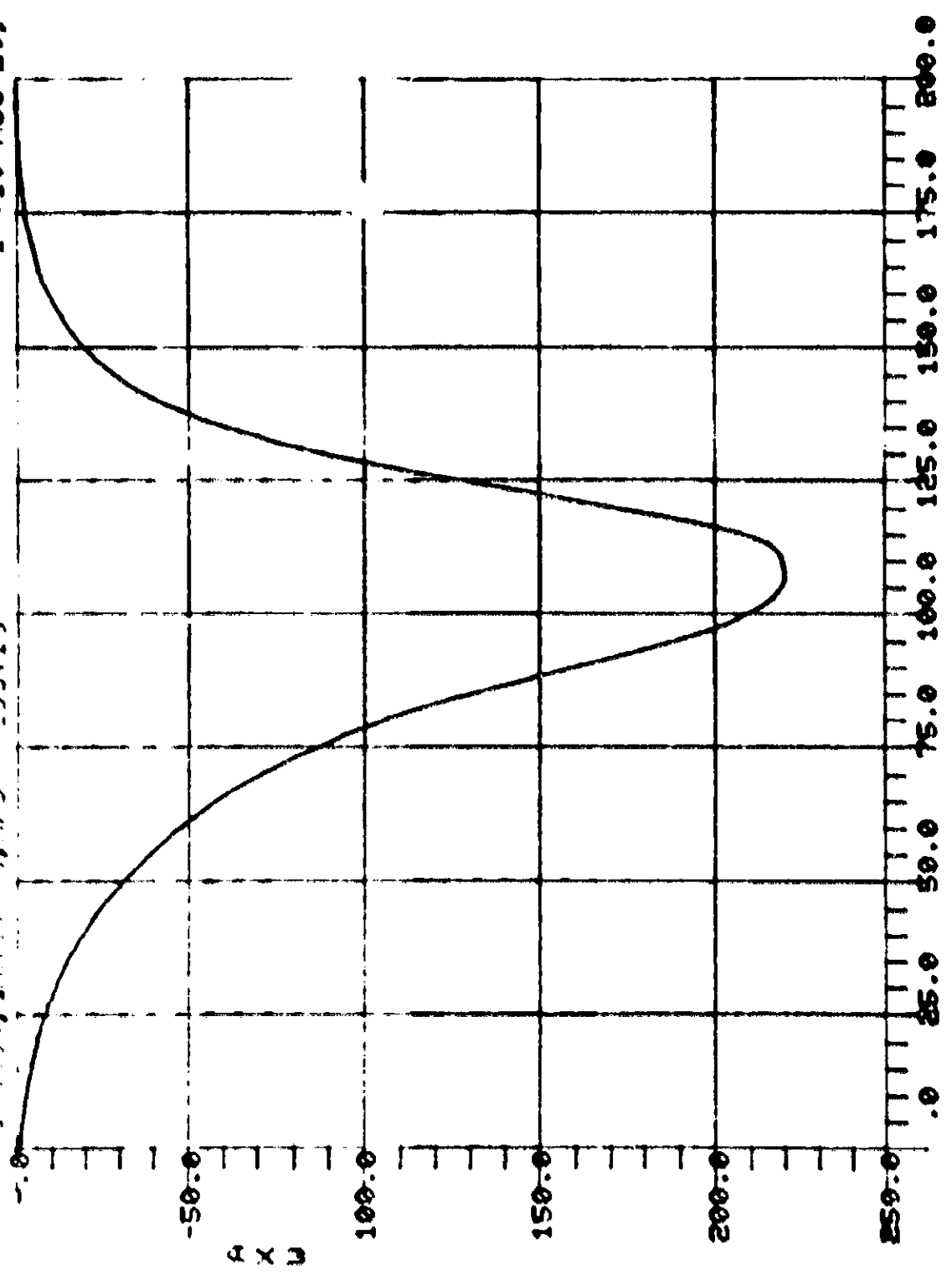


FIGURE 2-7

17110 AUG 20, '83

3.0015, 2.0010, 3.0015, 2.0010, 3.0015

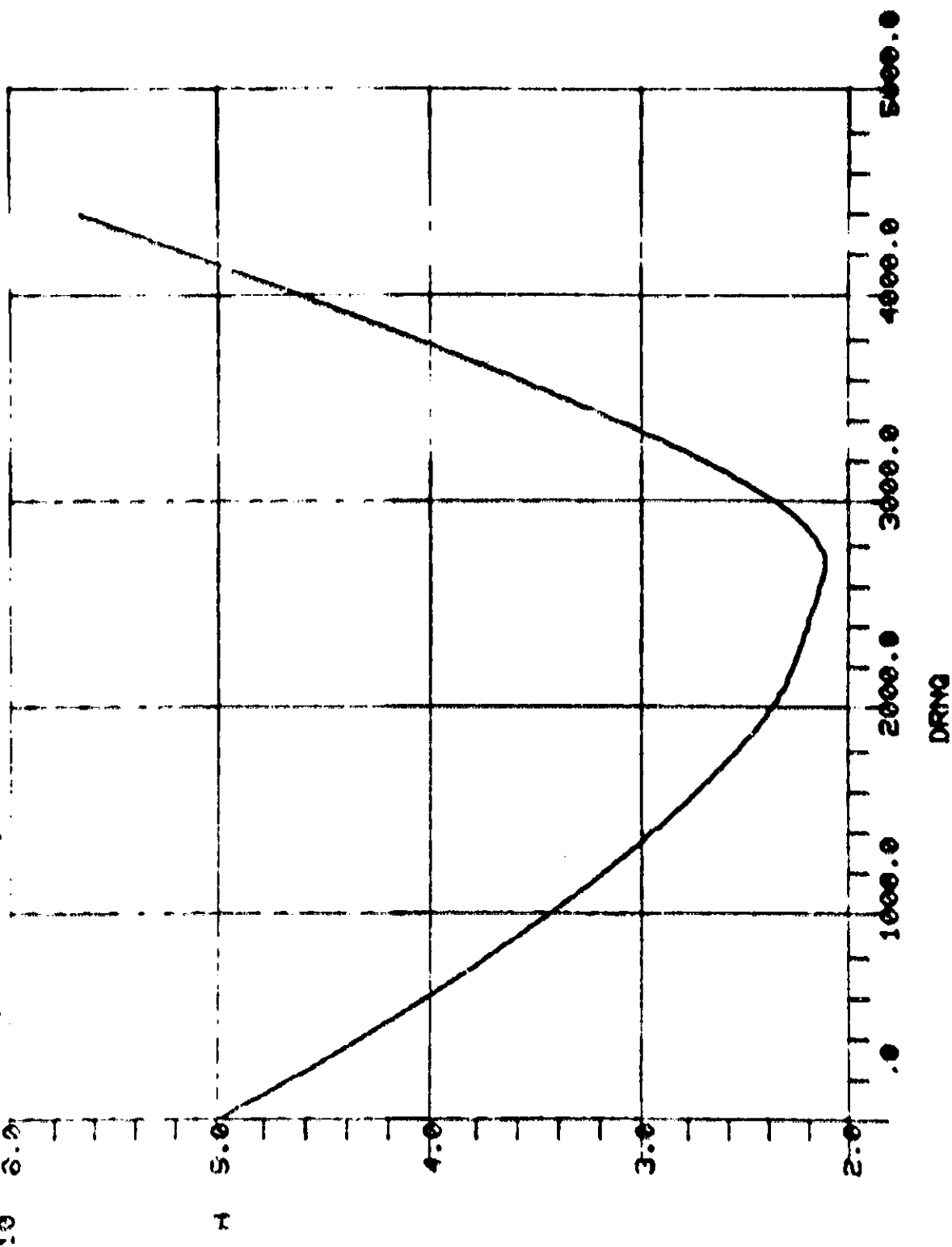


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FIGURE 1-0

16:55 AUG 28, '88

10-113, 54777-13, 4, 32-135.23



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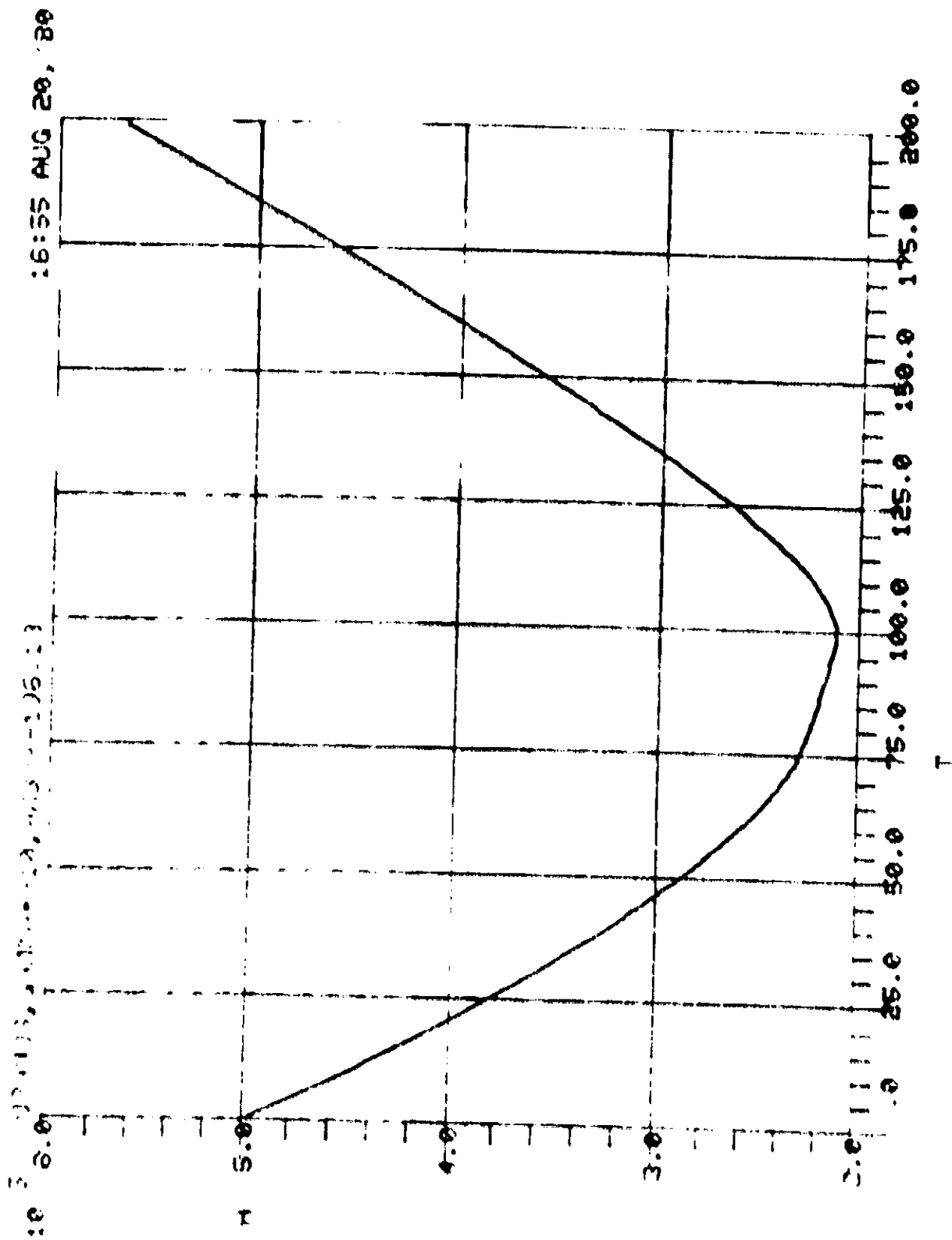


FIGURE C-11

16:55 AUG 20, '80

U26113, 25.17A-19.81J2-198.13

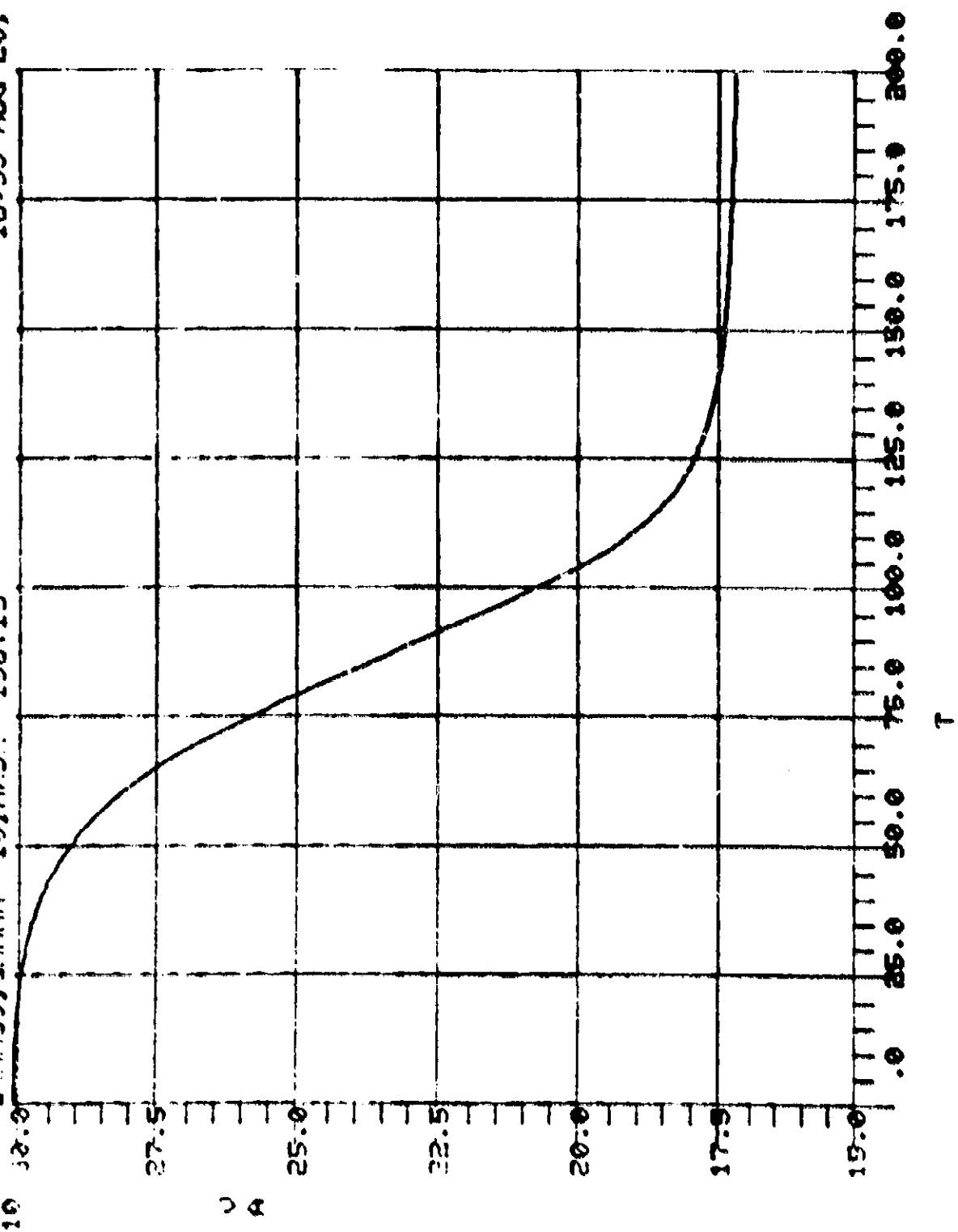


FIGURE 8-12

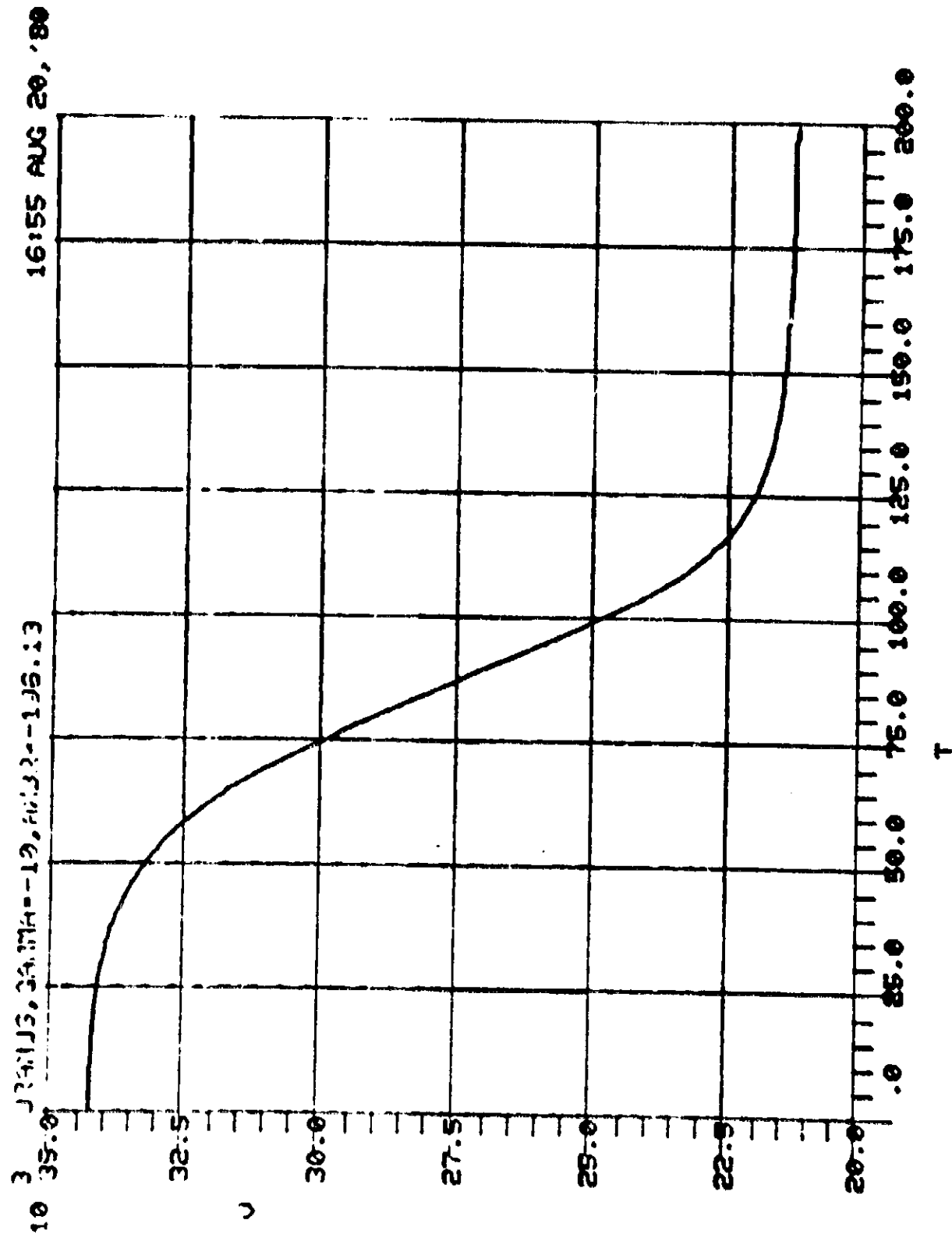


FIGURE C-13

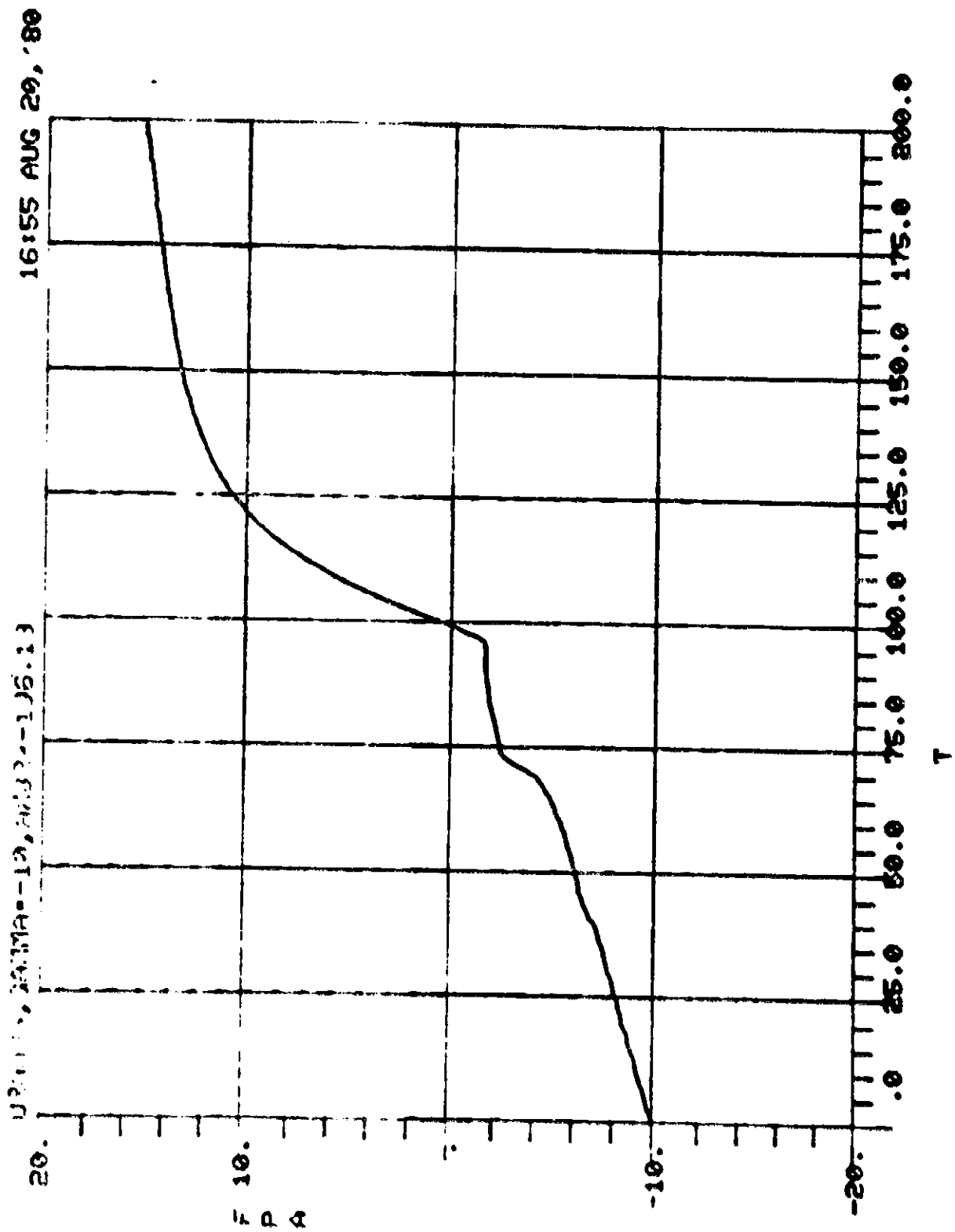


FIGURE C-14

16:55 AUG 20, '80

U24115, 241114-10, 20133-115.13

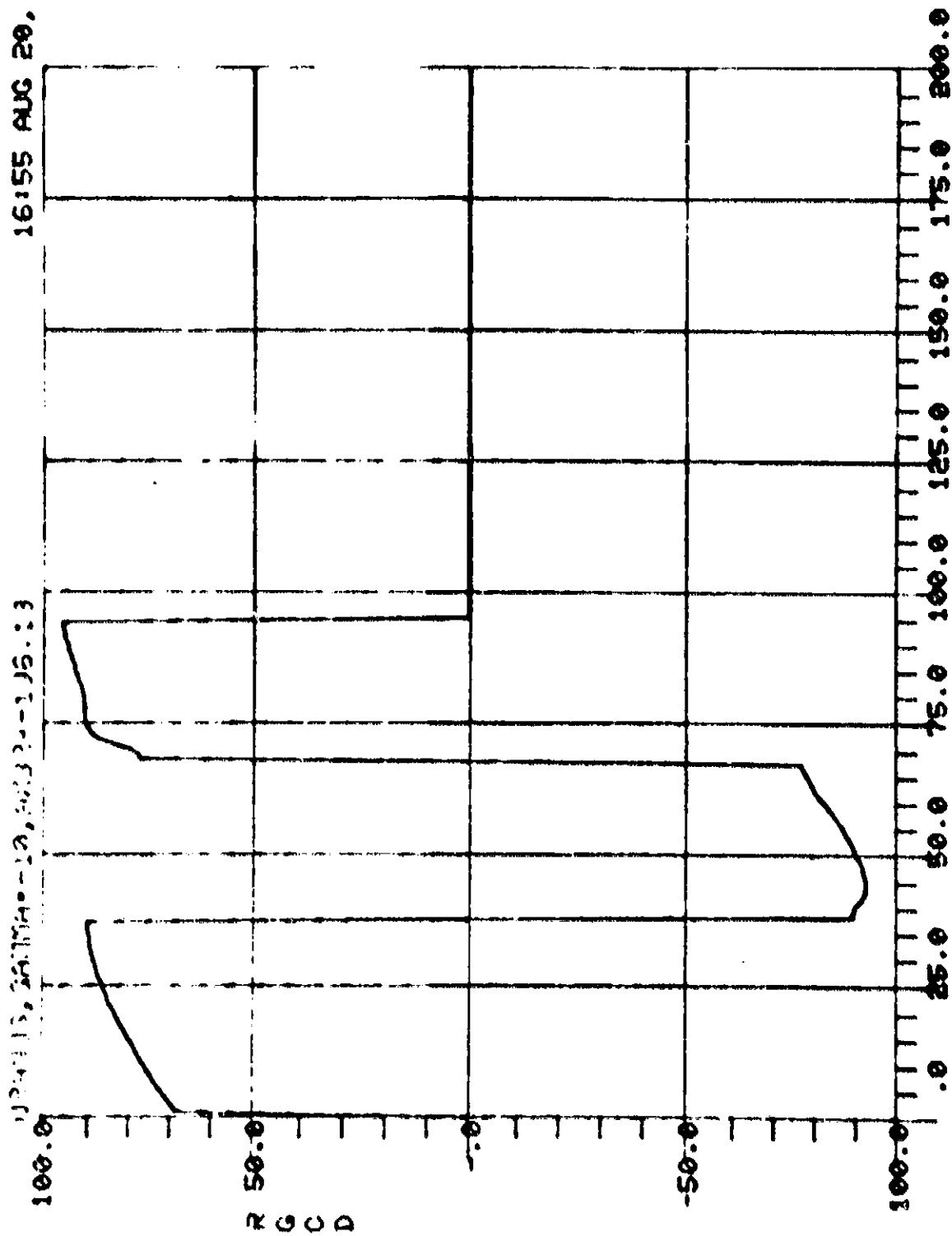
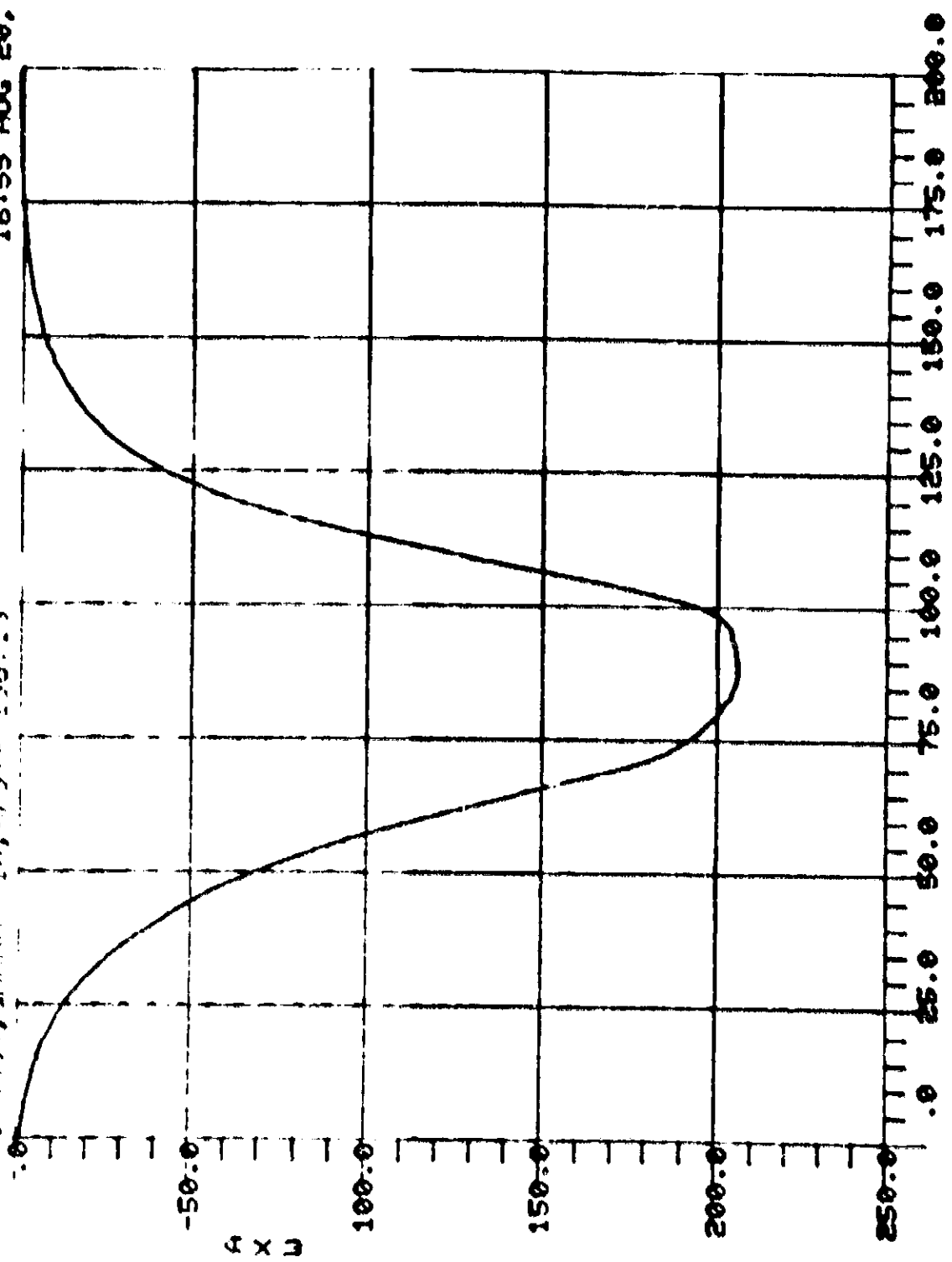


FIGURE 0-15

16:55 AUG 20, '80

13, 25, 37, 50, 75, 100, 125, 150, 175, 200



T

FIGURE 3-15

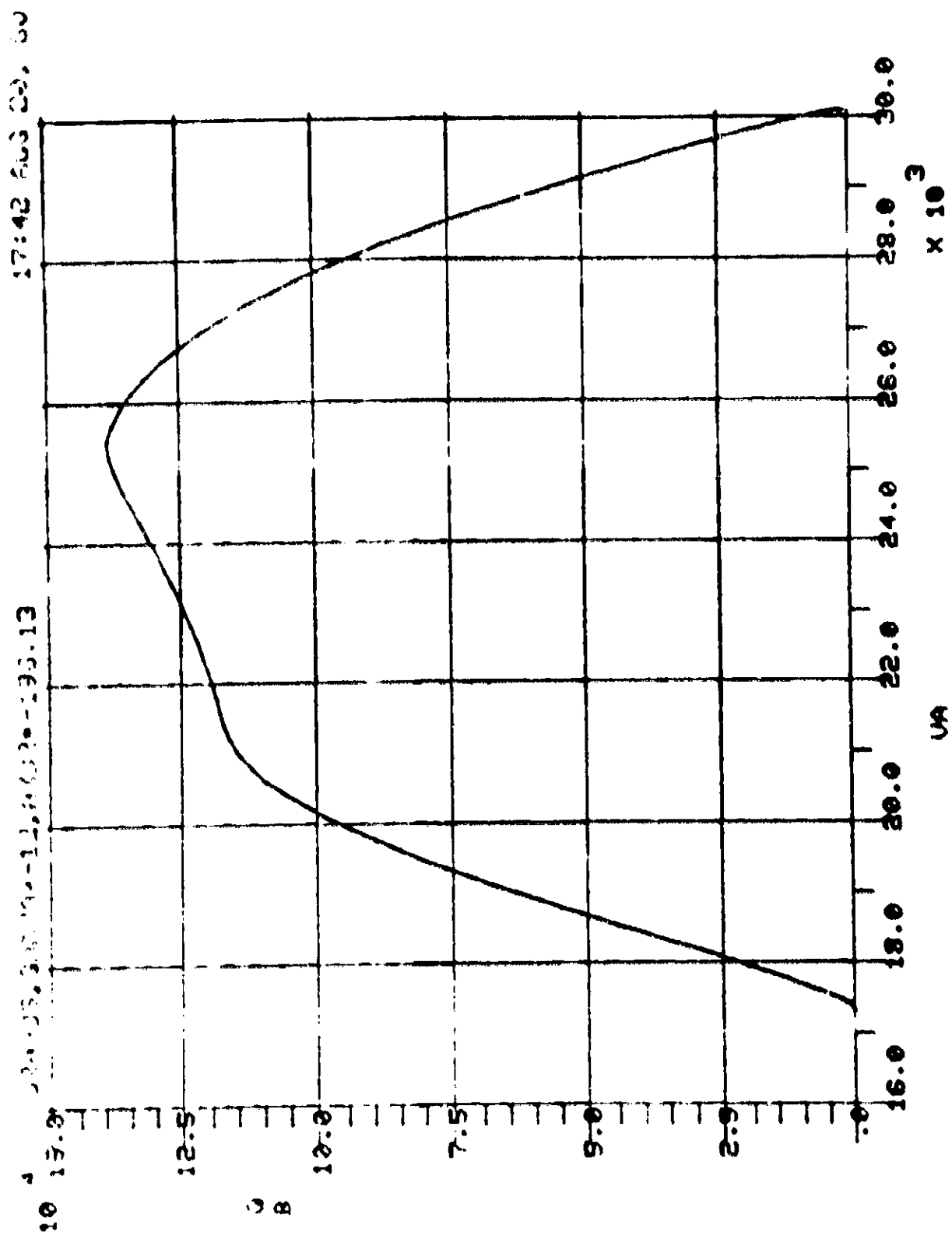
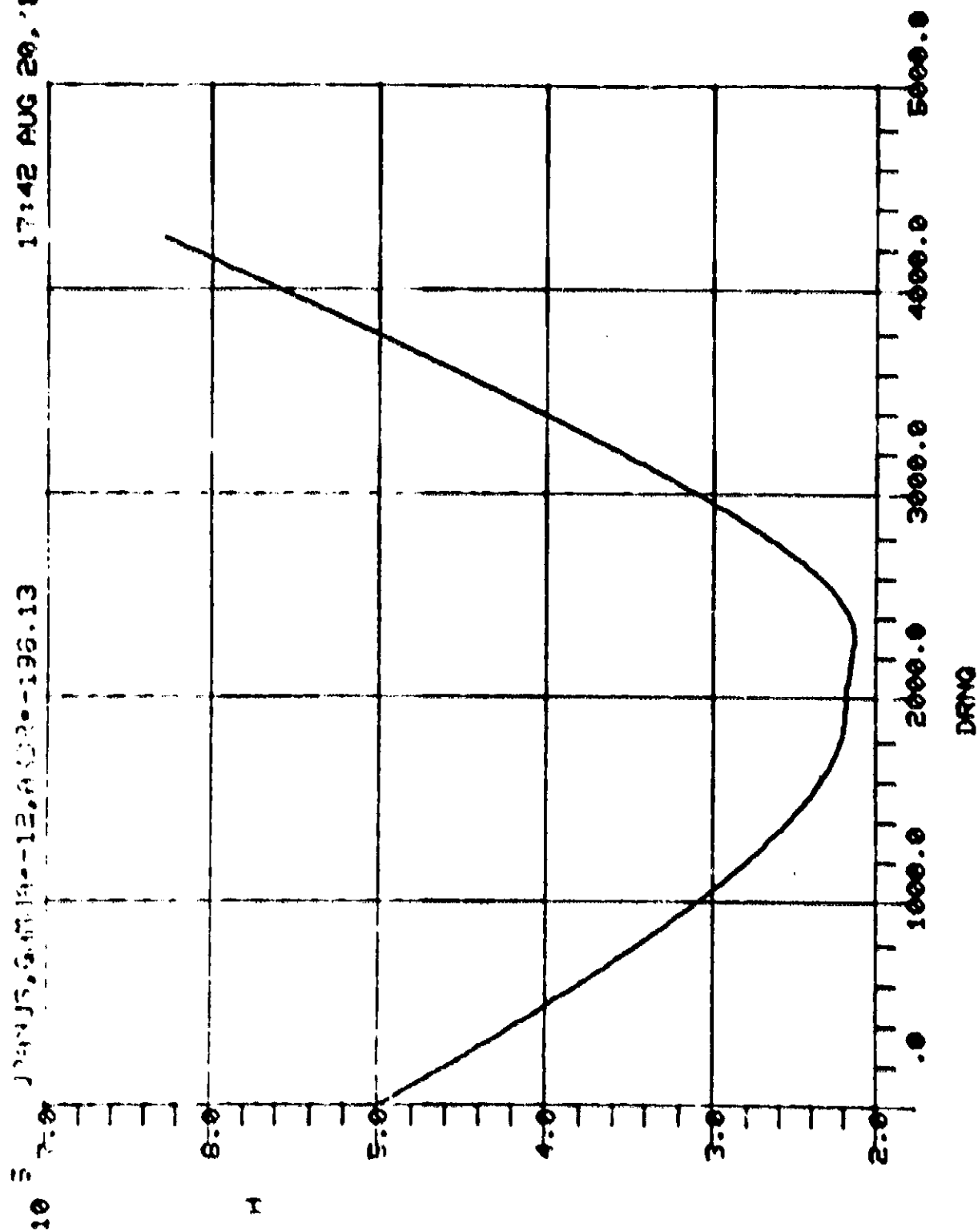


FIGURE C-17

17:42 AUG 20, '80

136.13-12,902-136.13



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0
0

10 5 JANUS, 3-11-14-12, AUG 20-196.13

17:42 AUG 20, '80

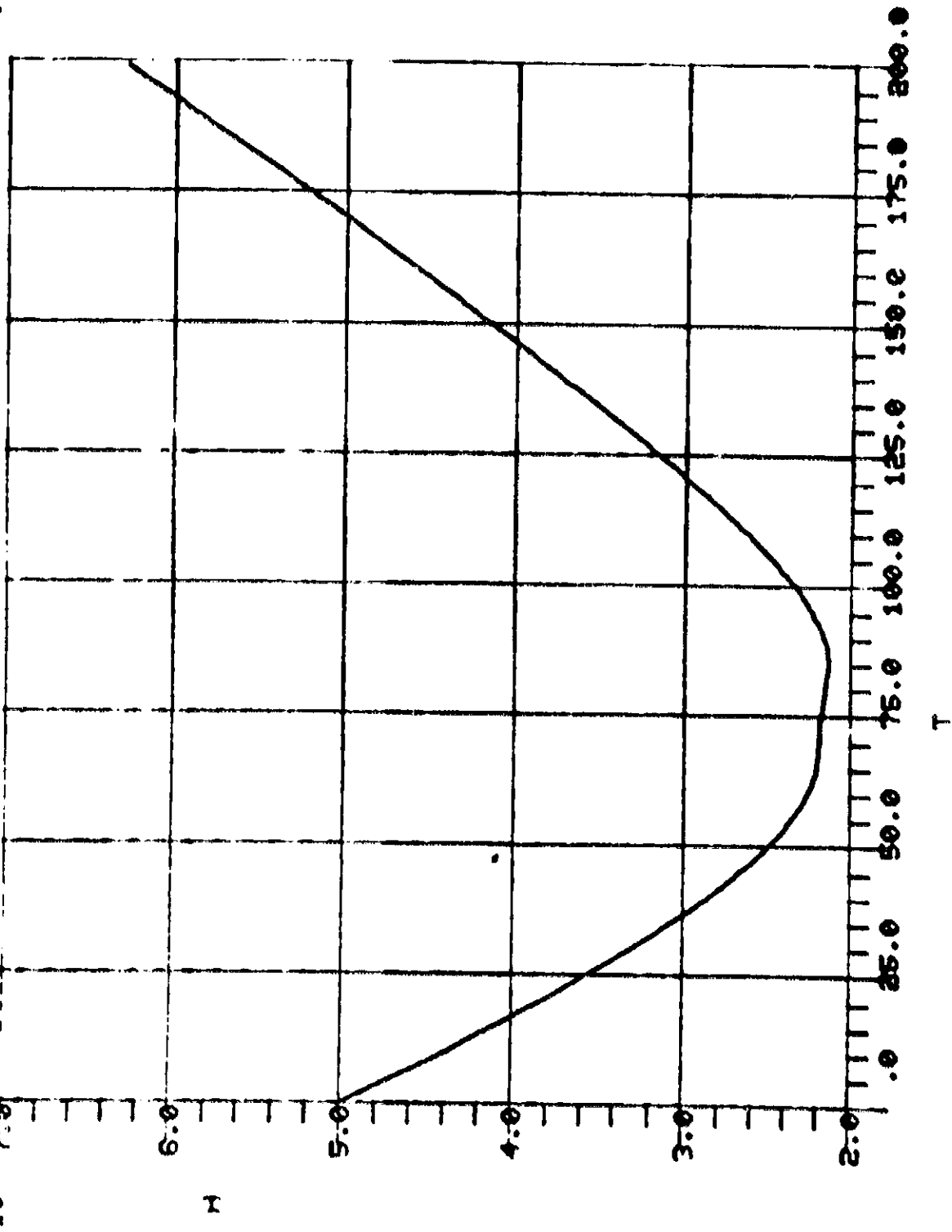
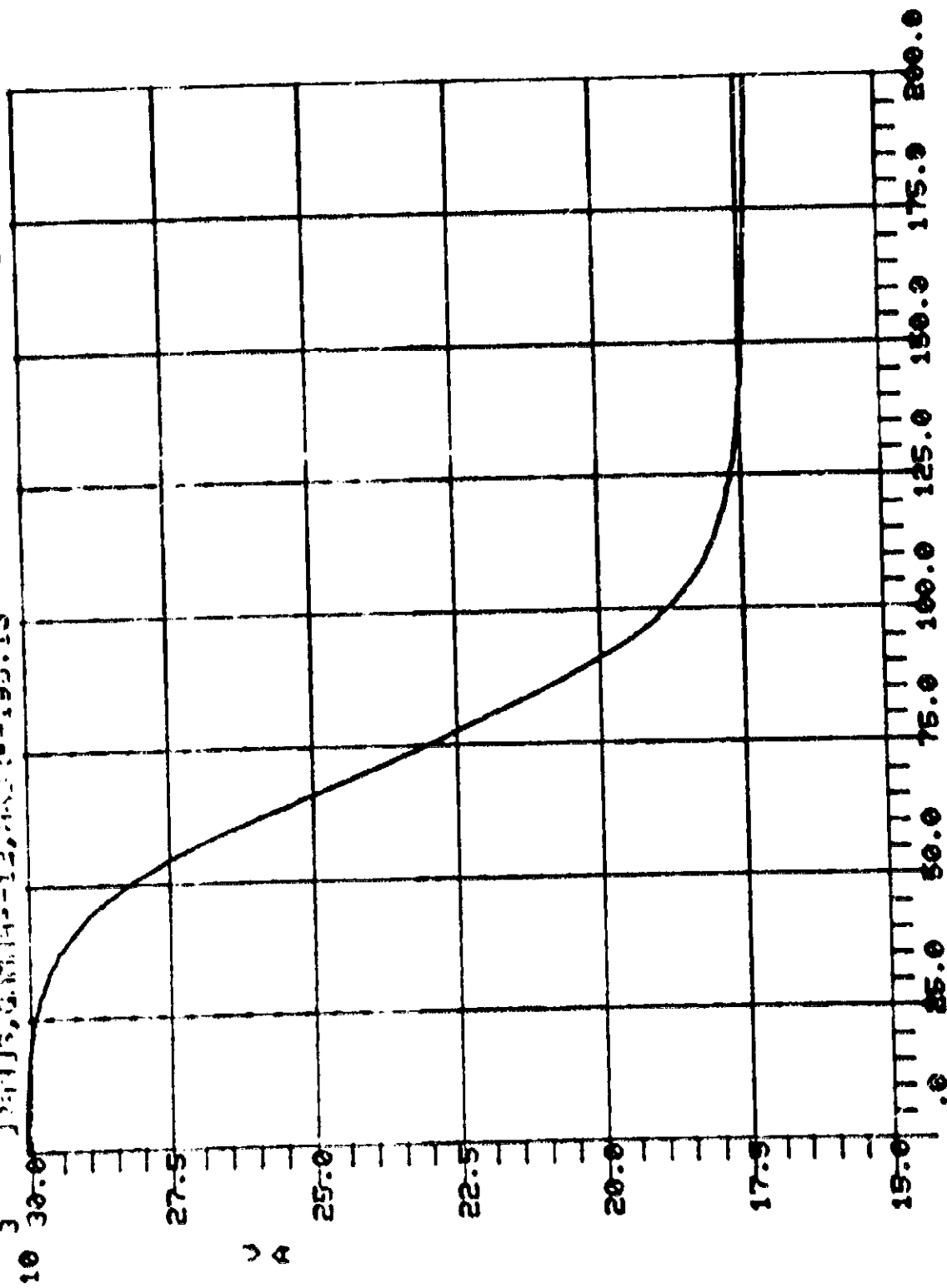


FIGURE C-10

17:42 AUG 20, '80

124115, G.M. 14-12, 64.2-135.13

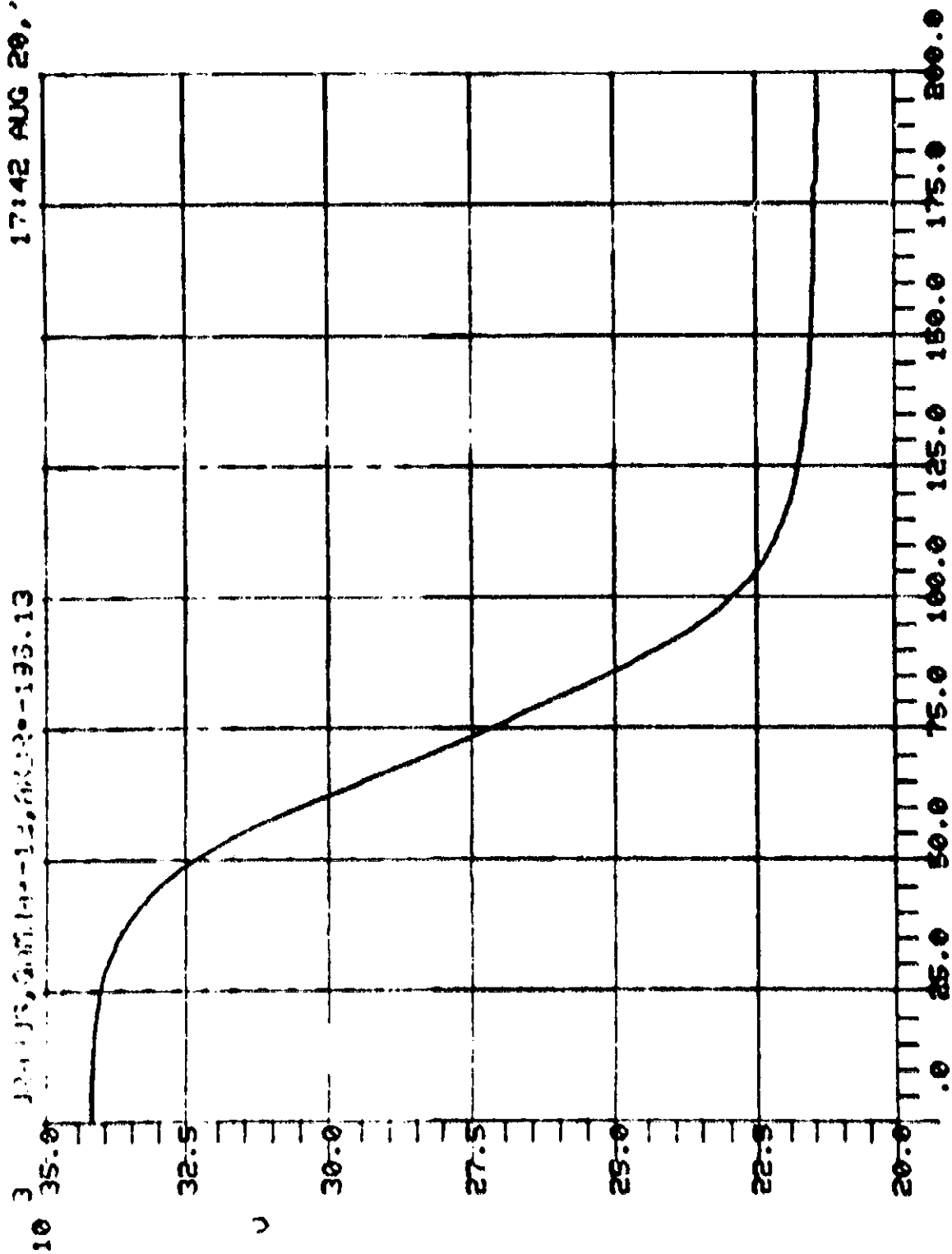


T

FIGURE C-22

17:42 AUG 20, '80

12-115, 207.14-12, 68220-135.13

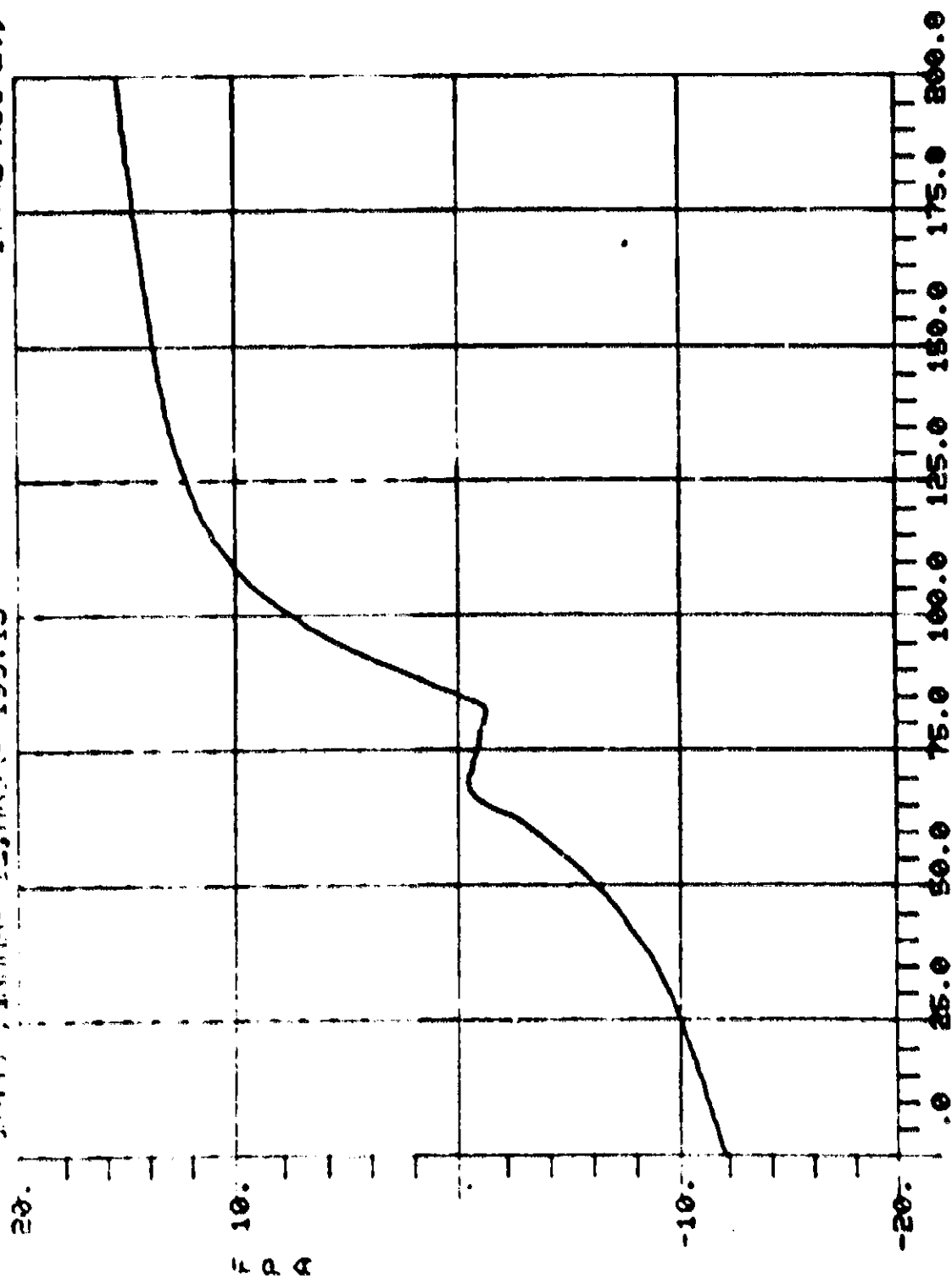


T

FIGURE C-21

17:42 AUG 20, '80

124417.45100-12.00000-193.13



T

FIGURE C-22

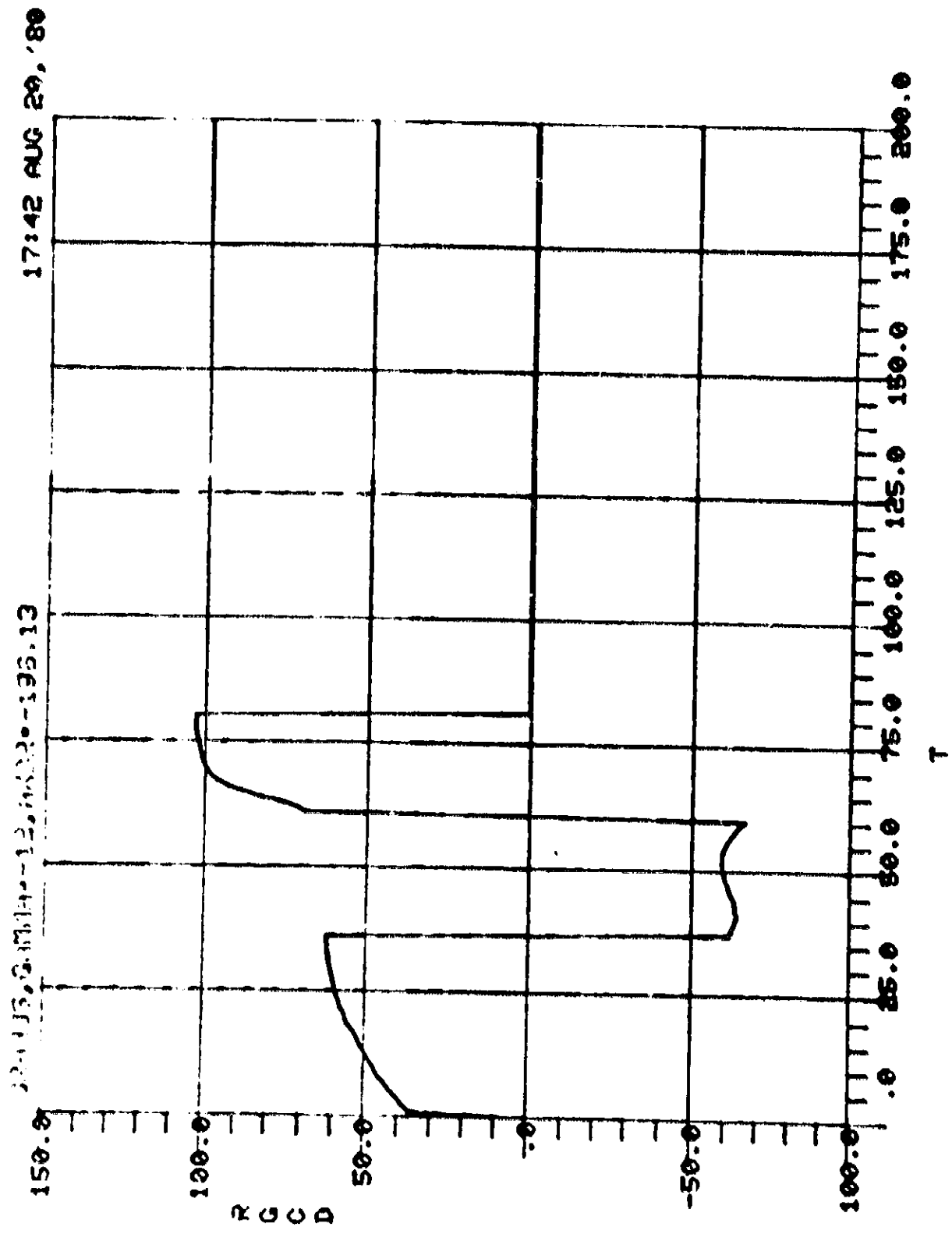
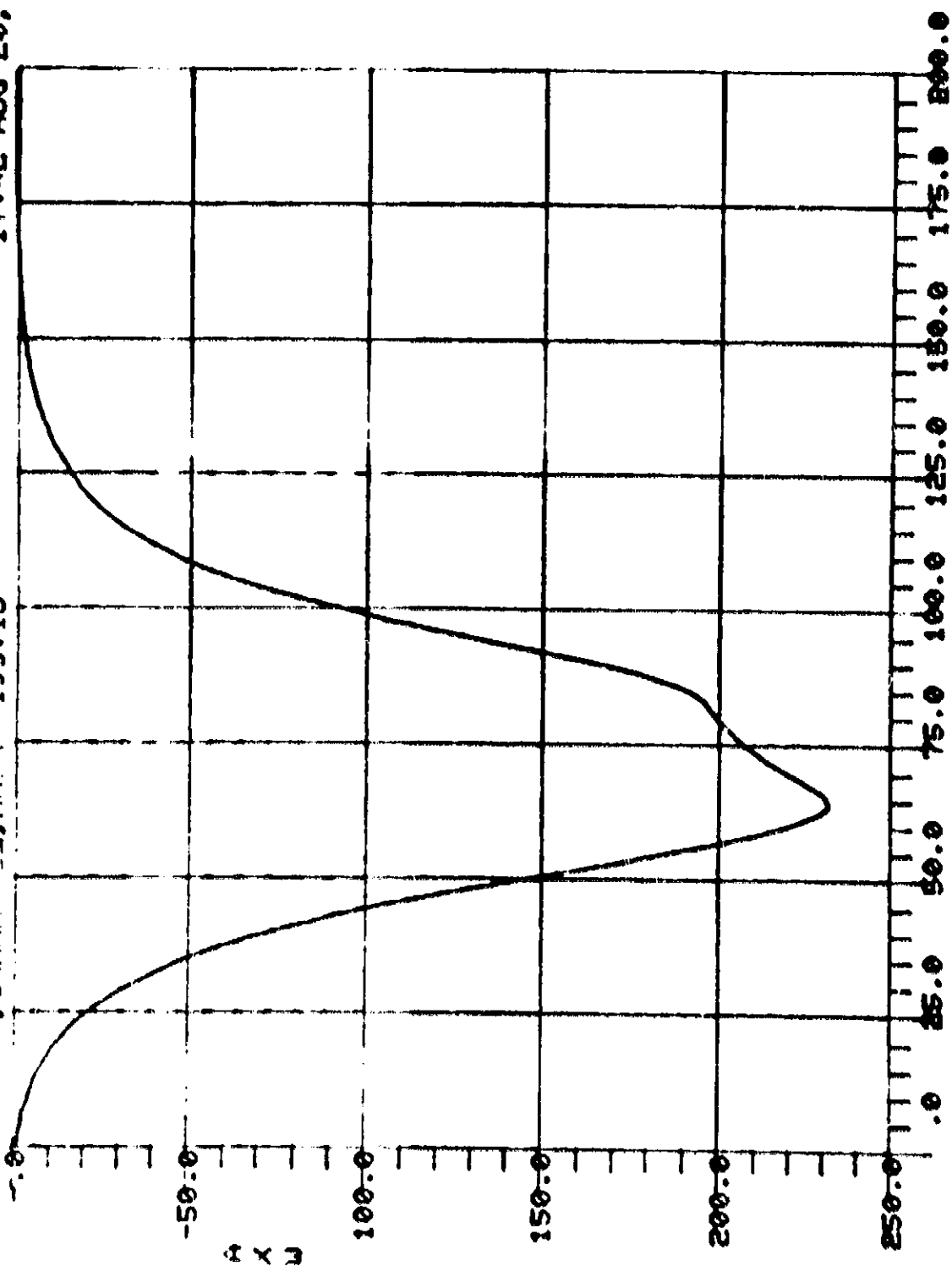


FIGURE C-23

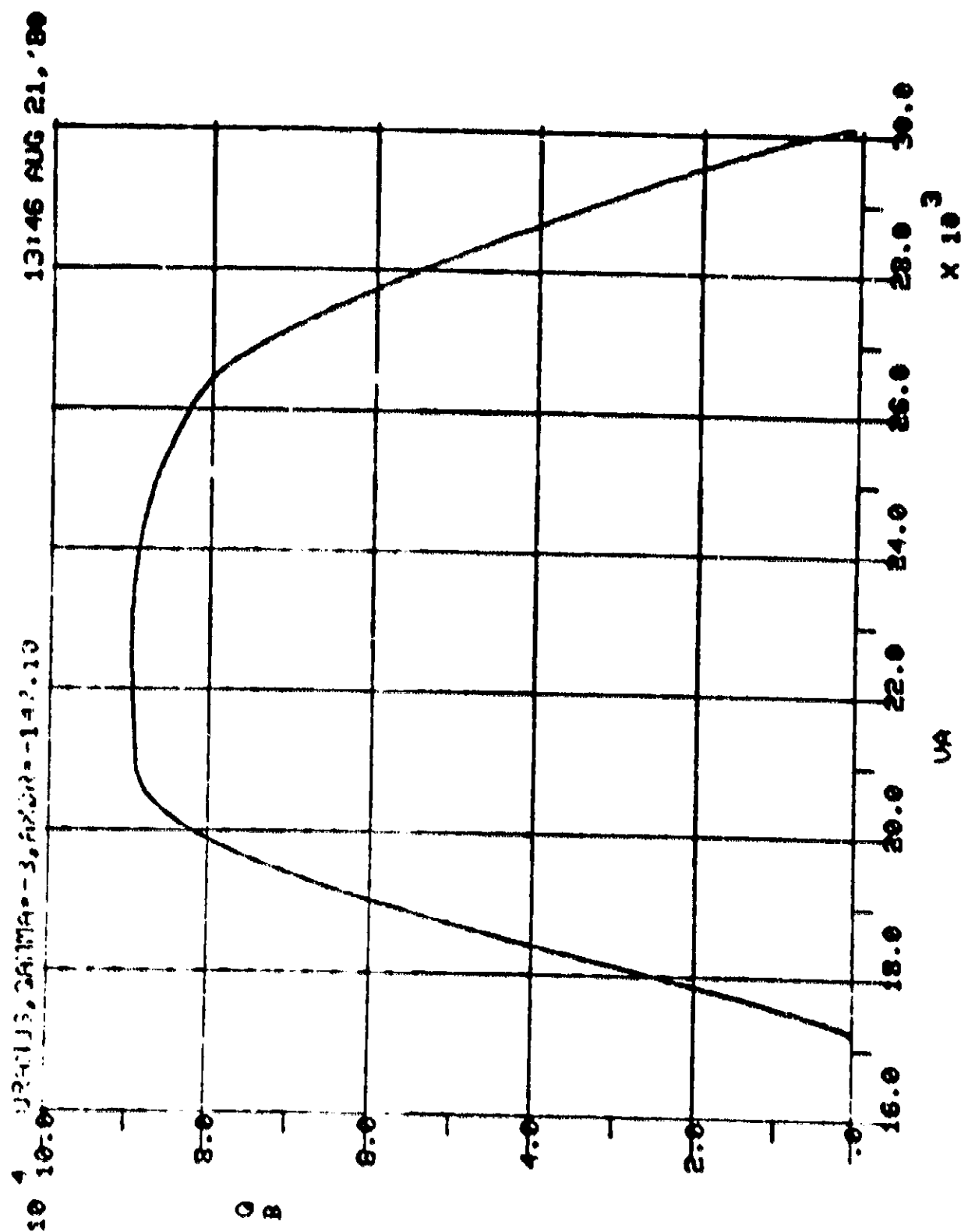
17:42 AUG 20, '80

13.24712-12.6012-193.13



T

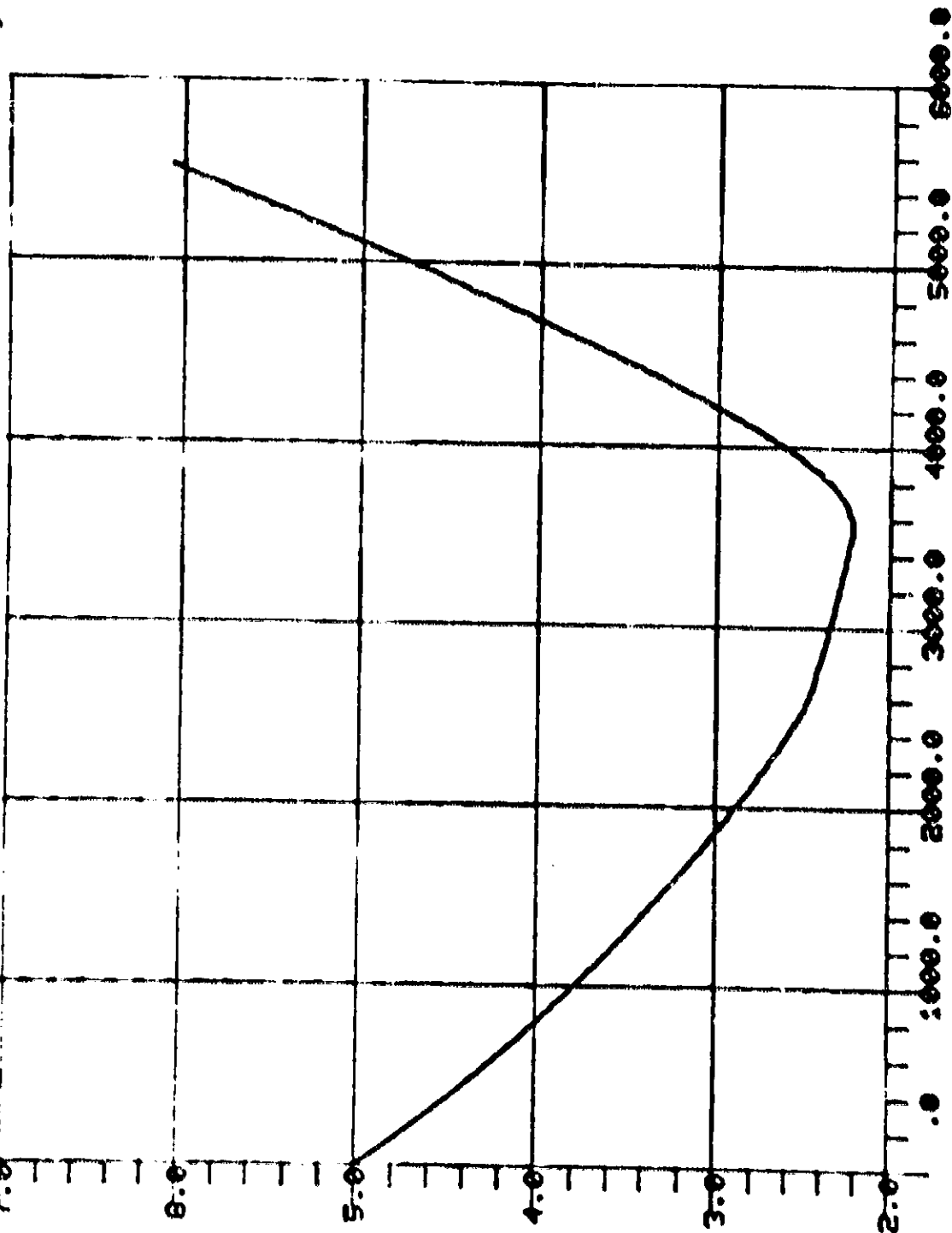
FIGURE C-24



13:46 AUG 13, '80

10 5 02-113, 2A.WA=-3, 2A.WR=-147.10

10 7.0



DRAG

FIGURE 3-25

10 5 URAHJ5, GAMMA=-3, AXOR=-147.13

13:46 AUG 21, '80

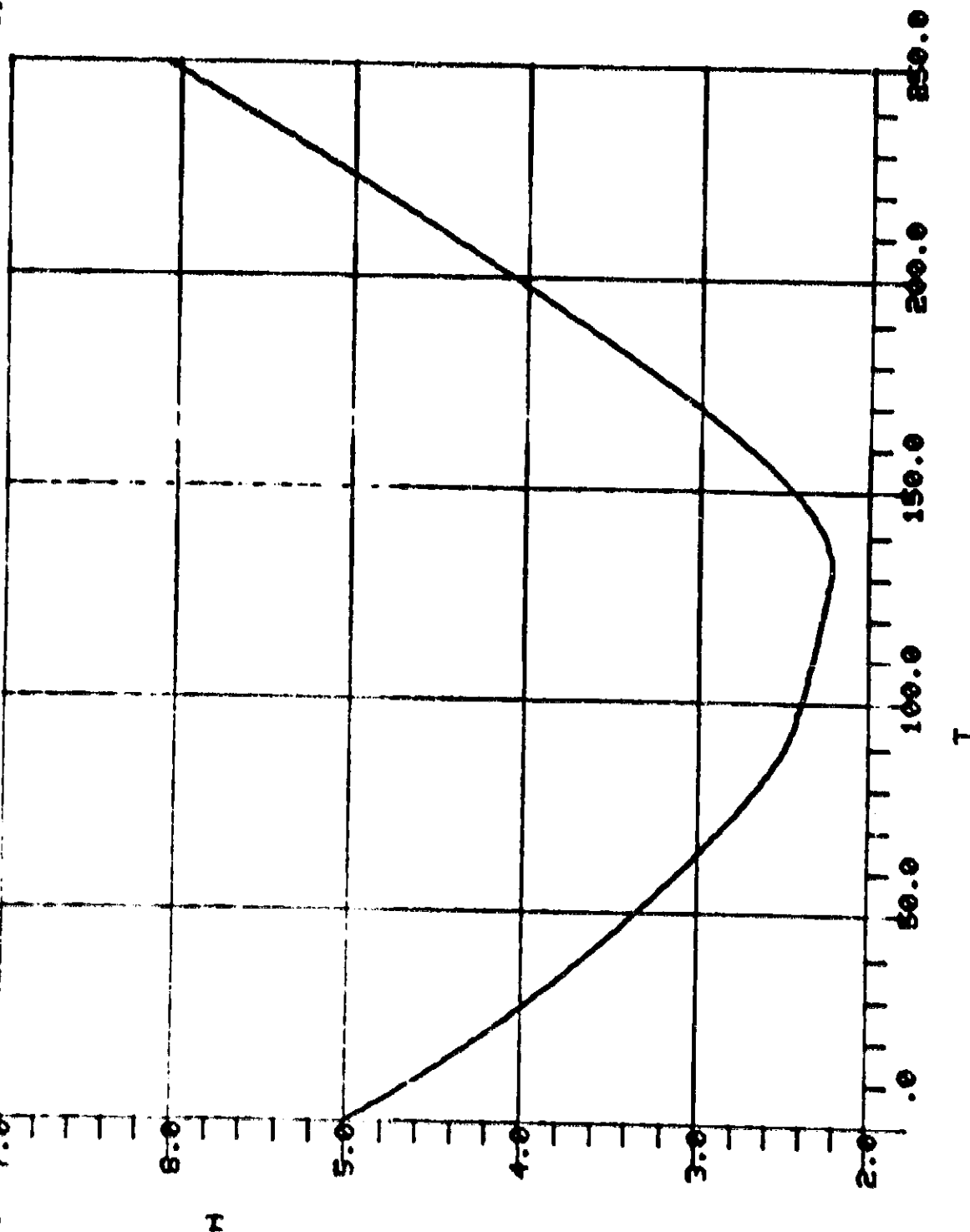


FIGURE C-27

13:46 AUG 21, '89

3 12.0113, 20.1714 - 3, 61.2120 - 147.20

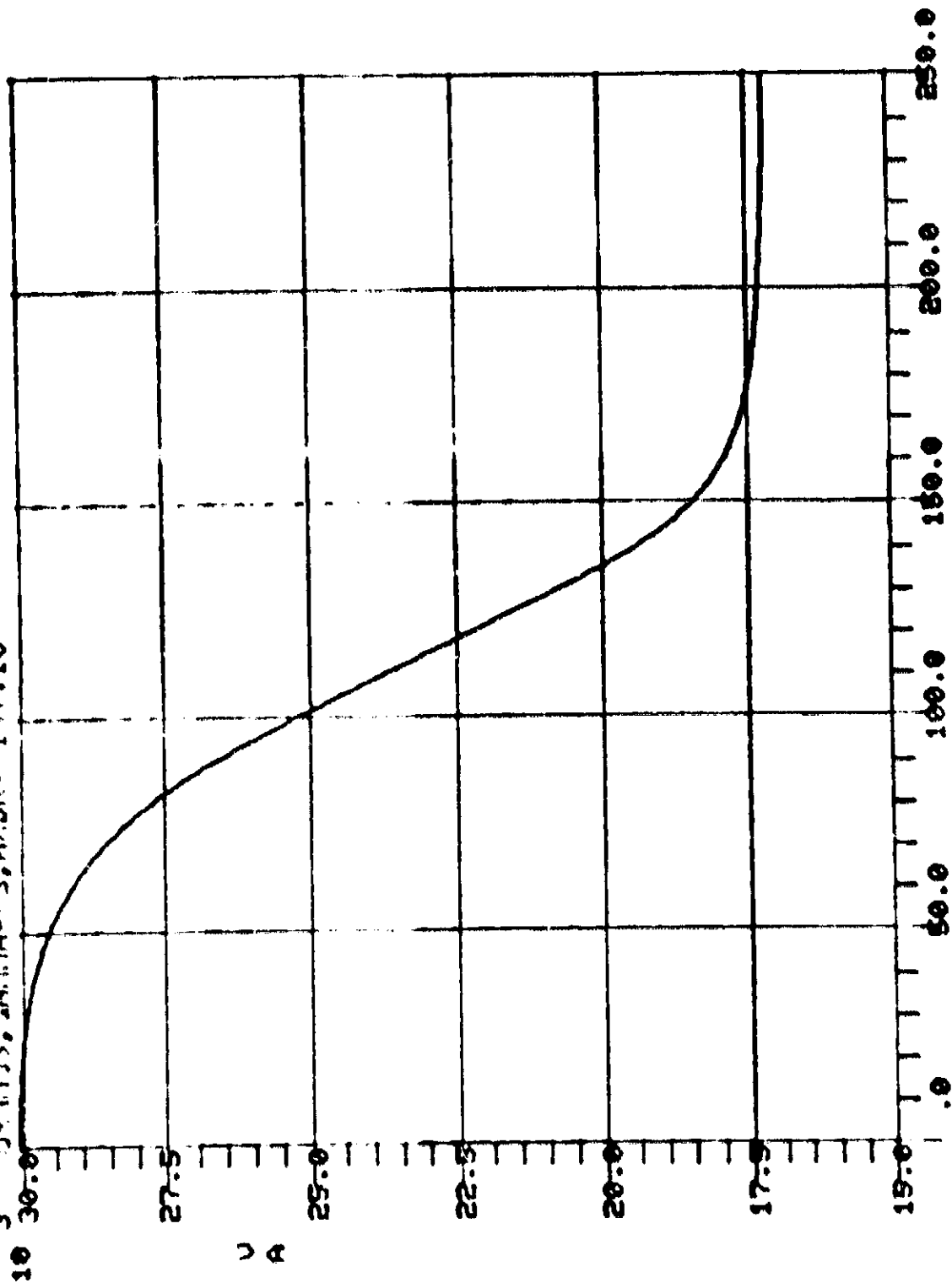


FIGURE C-22

13:46 AUG 21, '80

09-11.3, 34.374 = -3.47, 0.00 = -14.7. 1.0

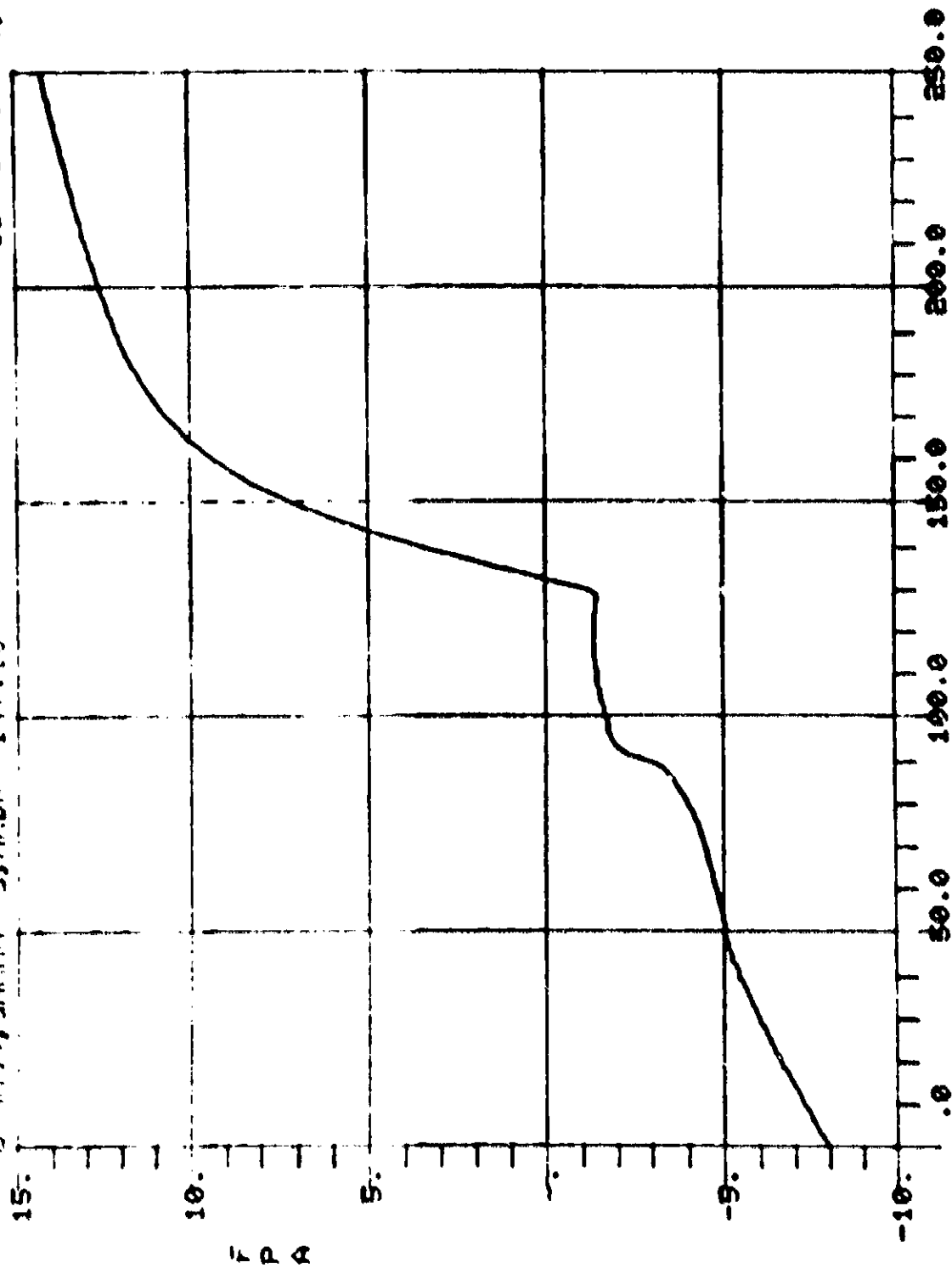


FIGURE C-30

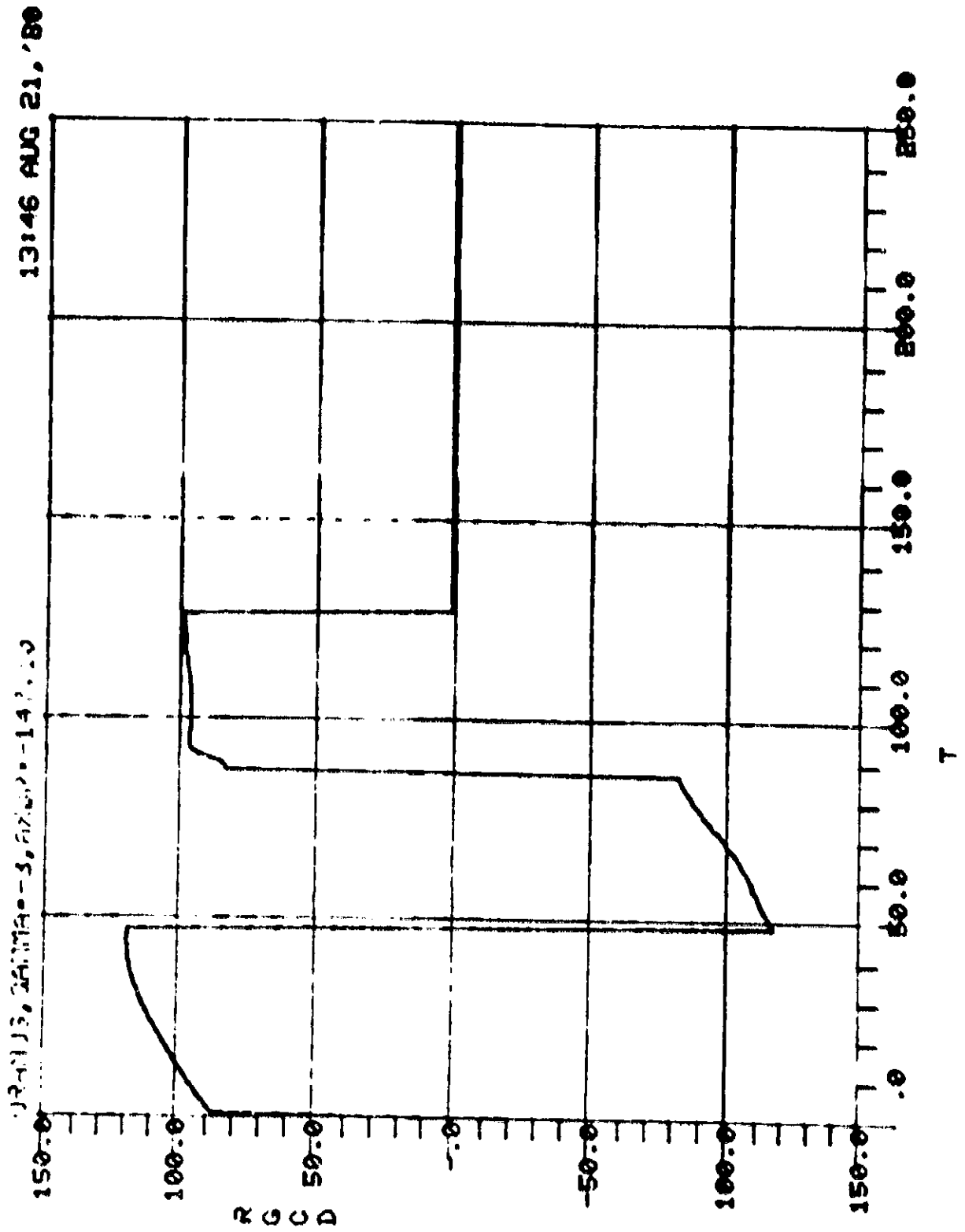


FIGURE C-31

13146 AUG 21, '80

13146 AUG 21, '80

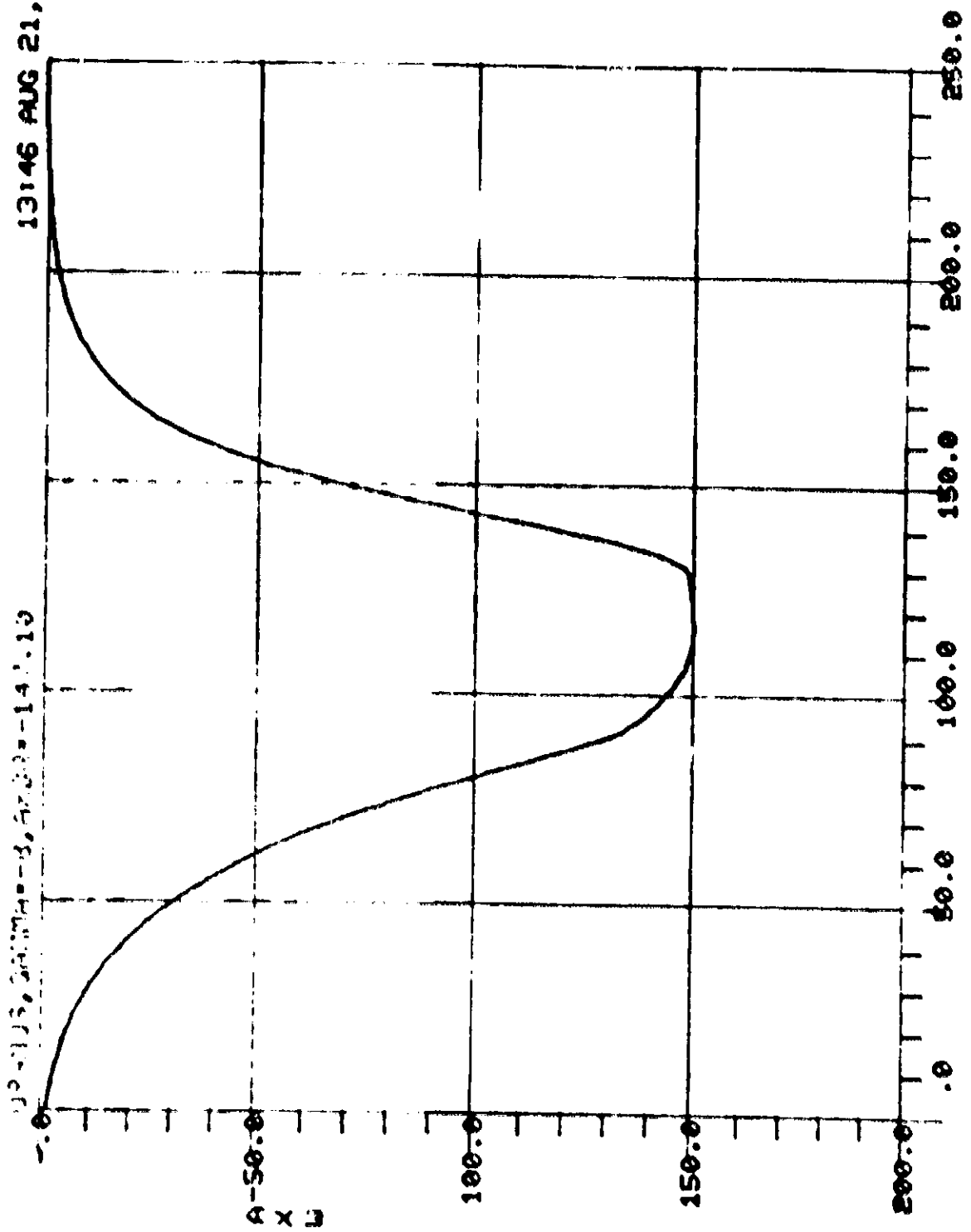


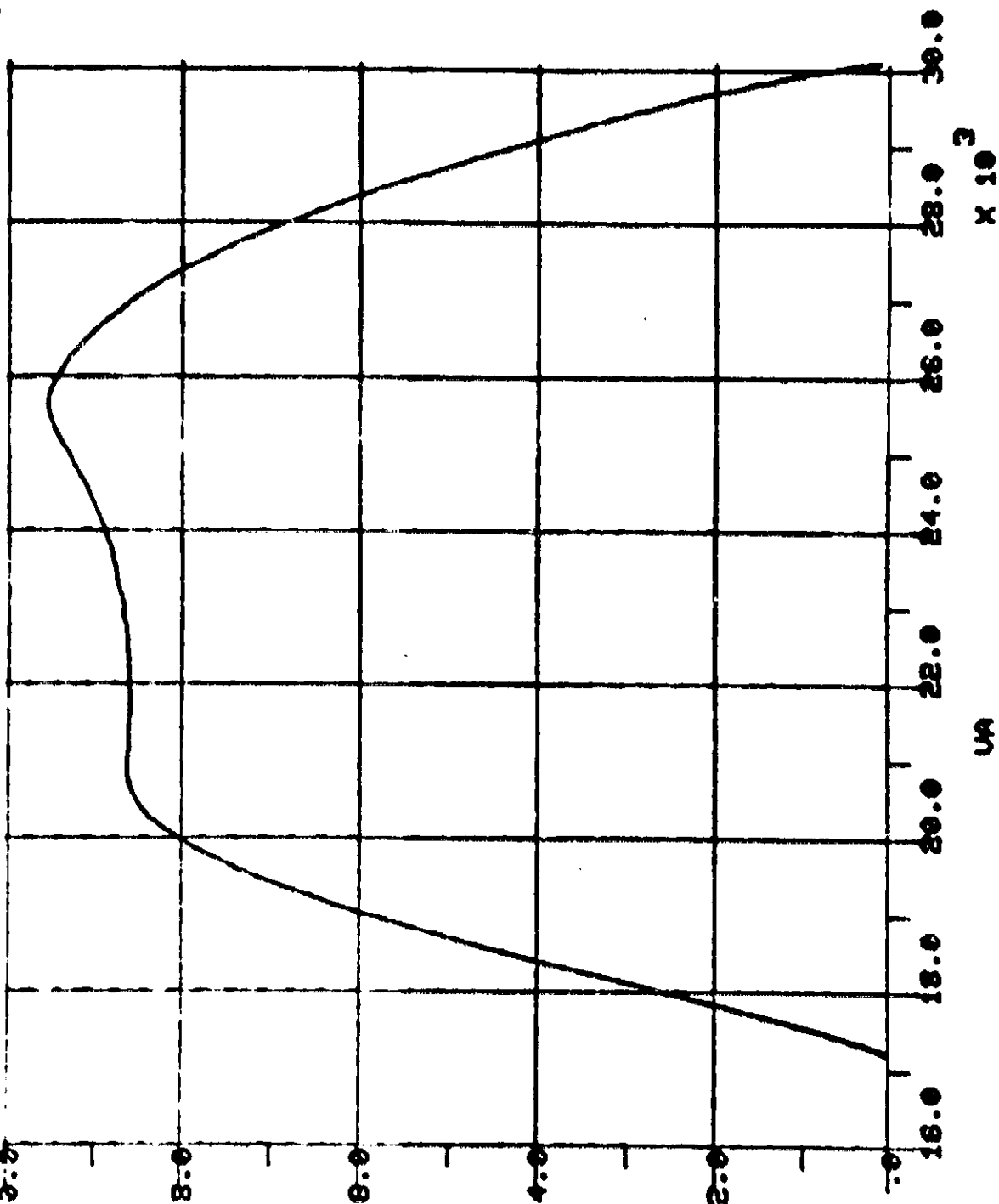
FIGURE C-32

13:34 AUG 21, '80

JJN15, 2.30194-19, AK32=-147.10

10 12:0

0 B



UA

x 10³

FIGURE C-33

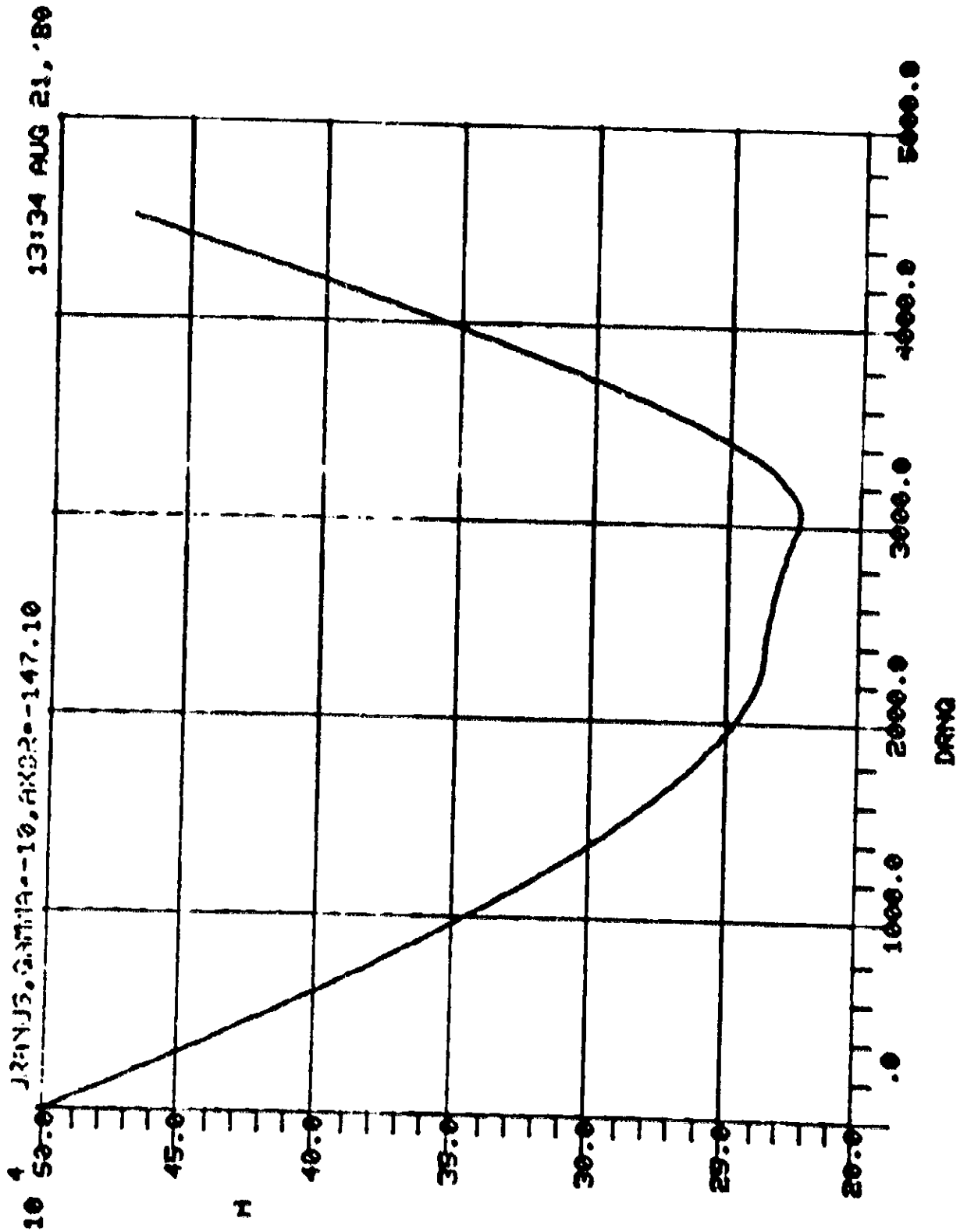


FIGURE C-34

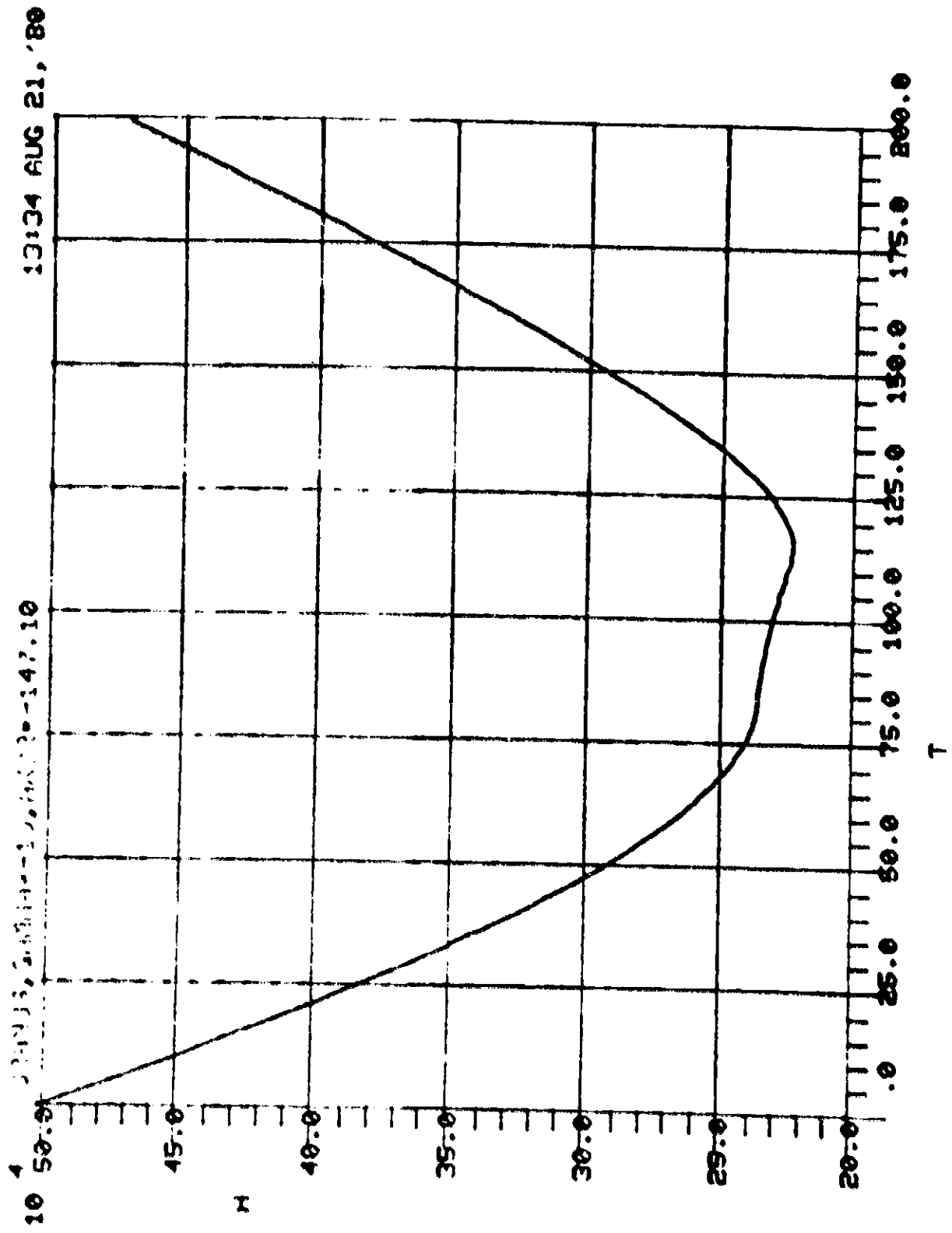
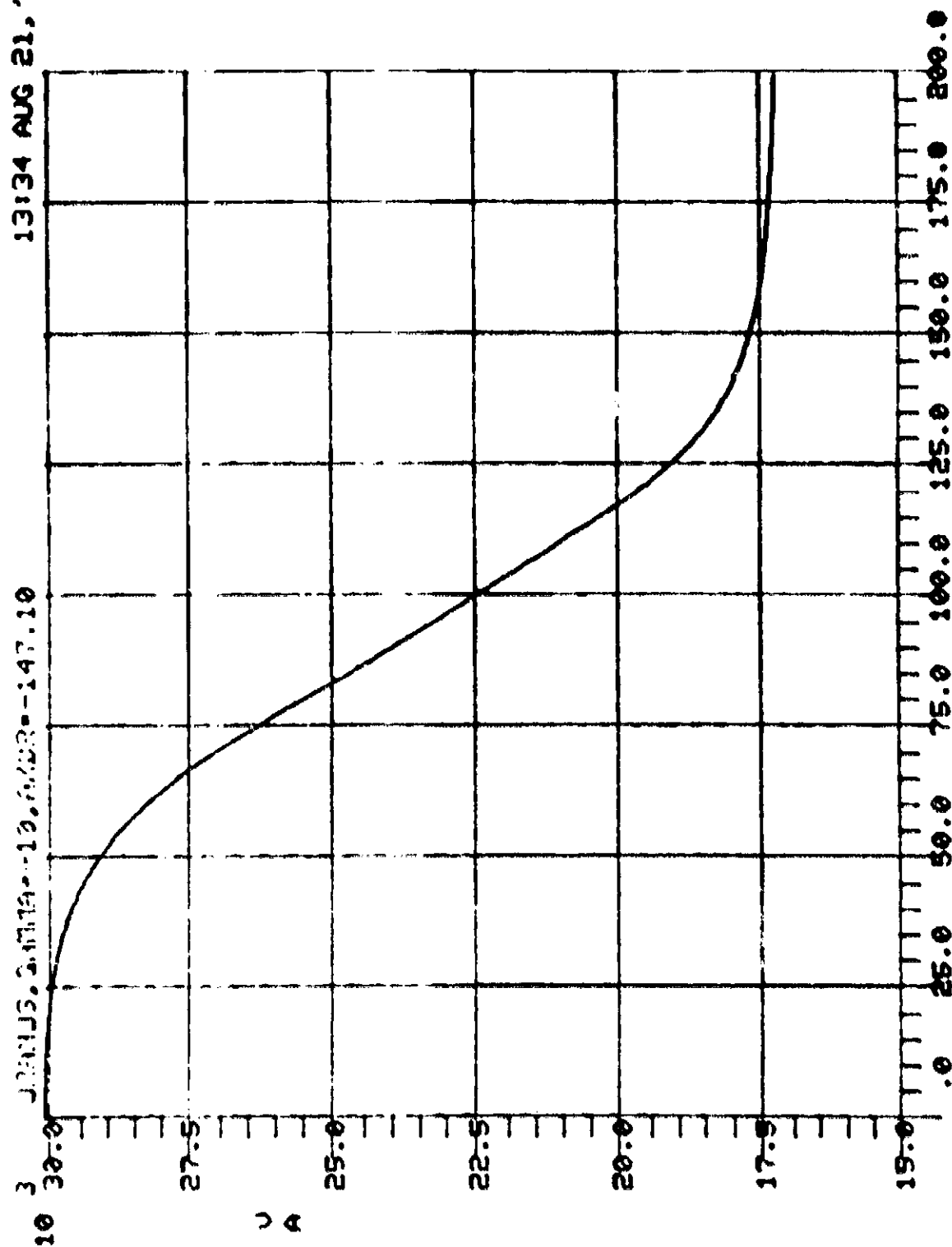


FIGURE 0-35

13:34 AUG 21, '80

JUNUS, 3.7119-10, 6.02R-147.10



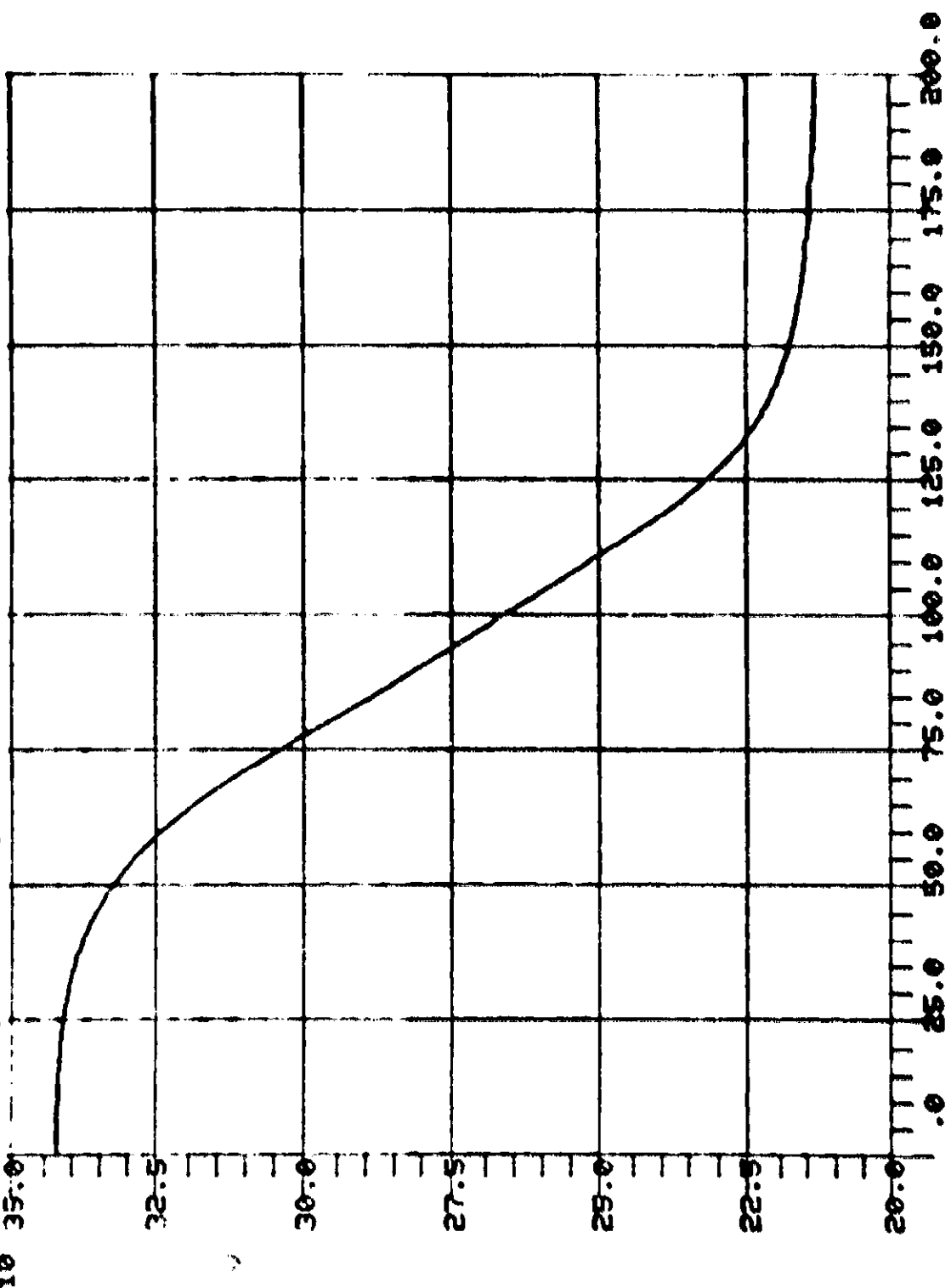
T

FIGURE 3-16

10 3 35:0

J24115, 2.4115-10, ANDR--147.10

13:34 AUG 21, '80



T
FIGURE C-3

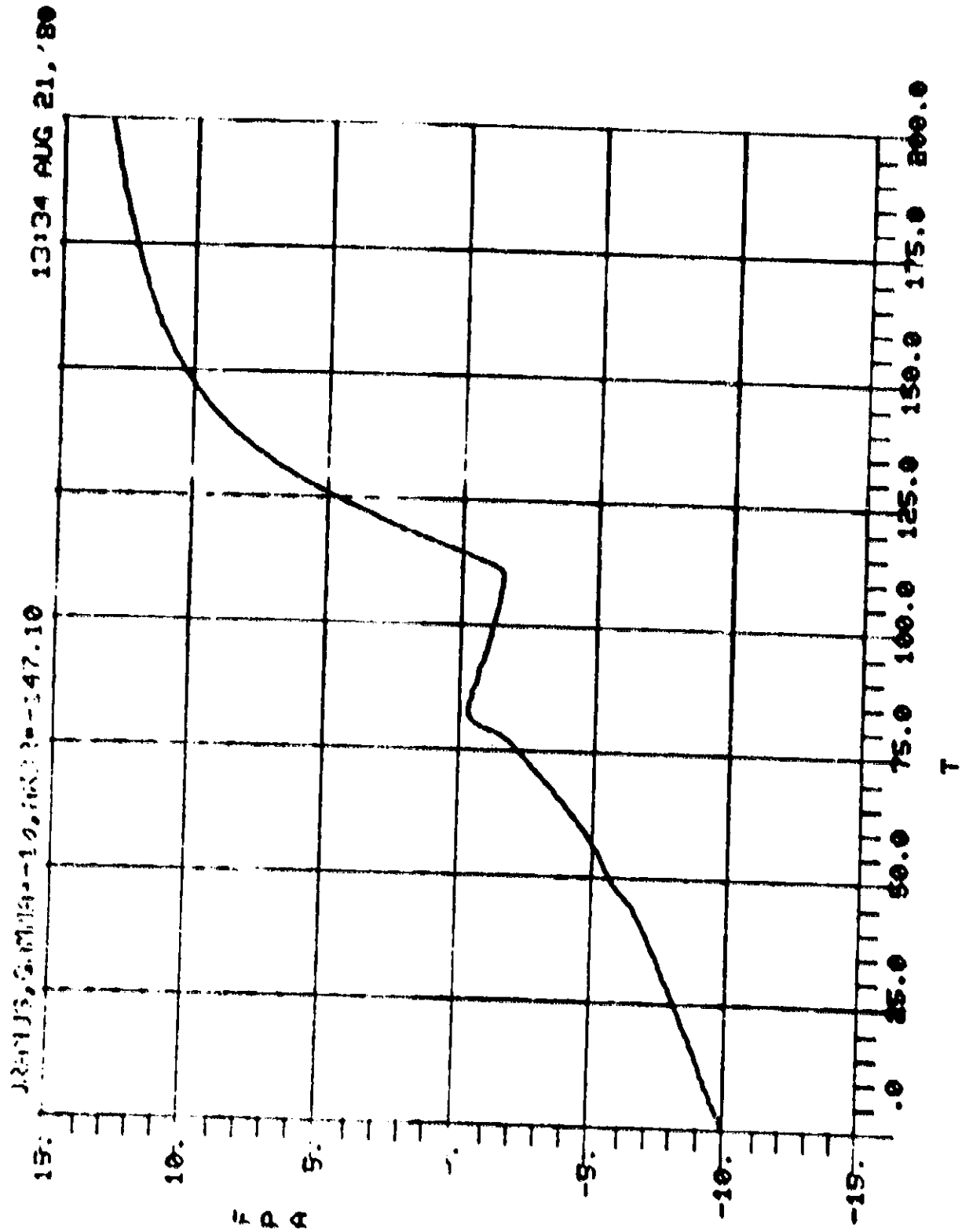


FIGURE 3-30

13:34 AUG 21, '80

020435, 2.67449-10, 608.2-147.10

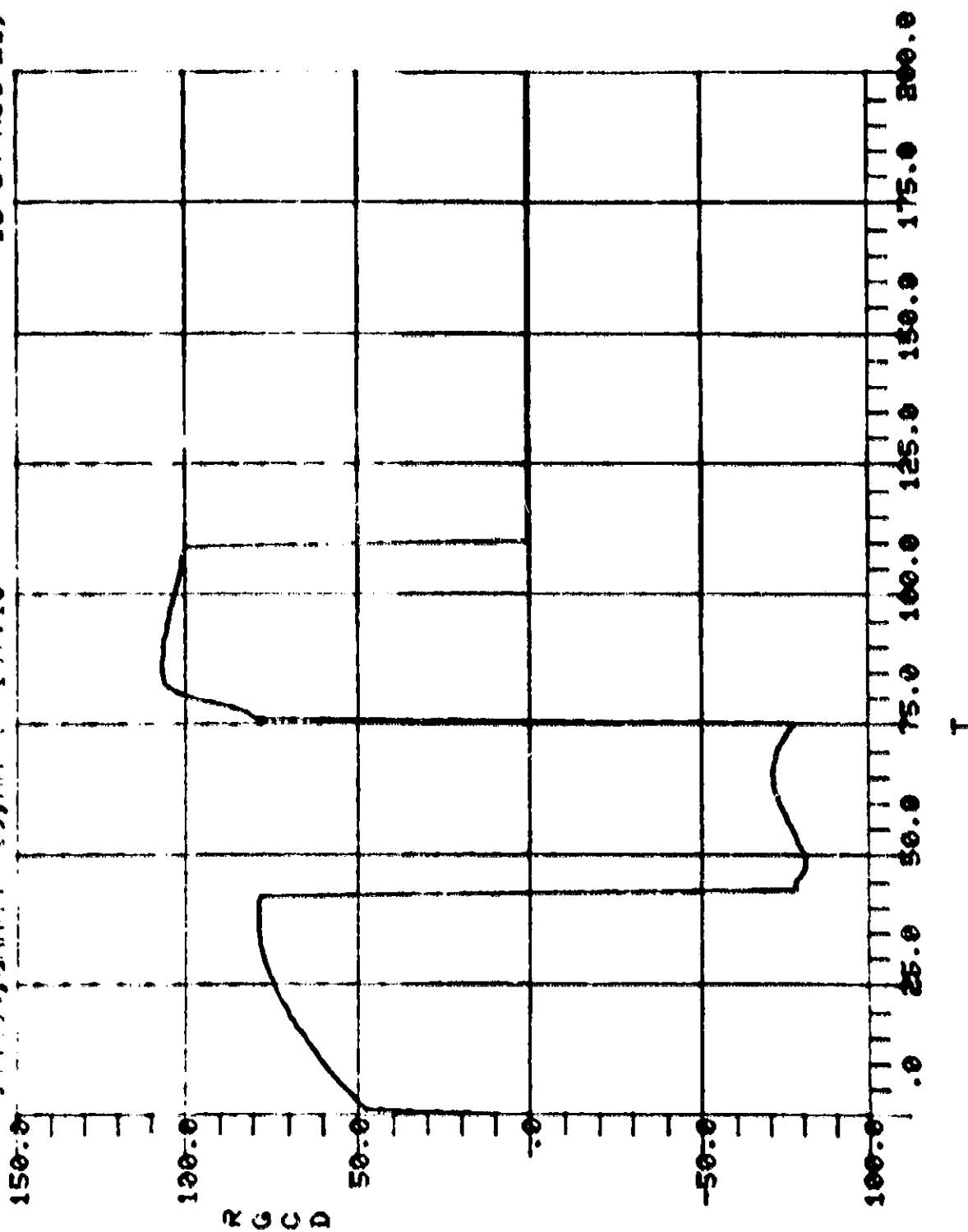
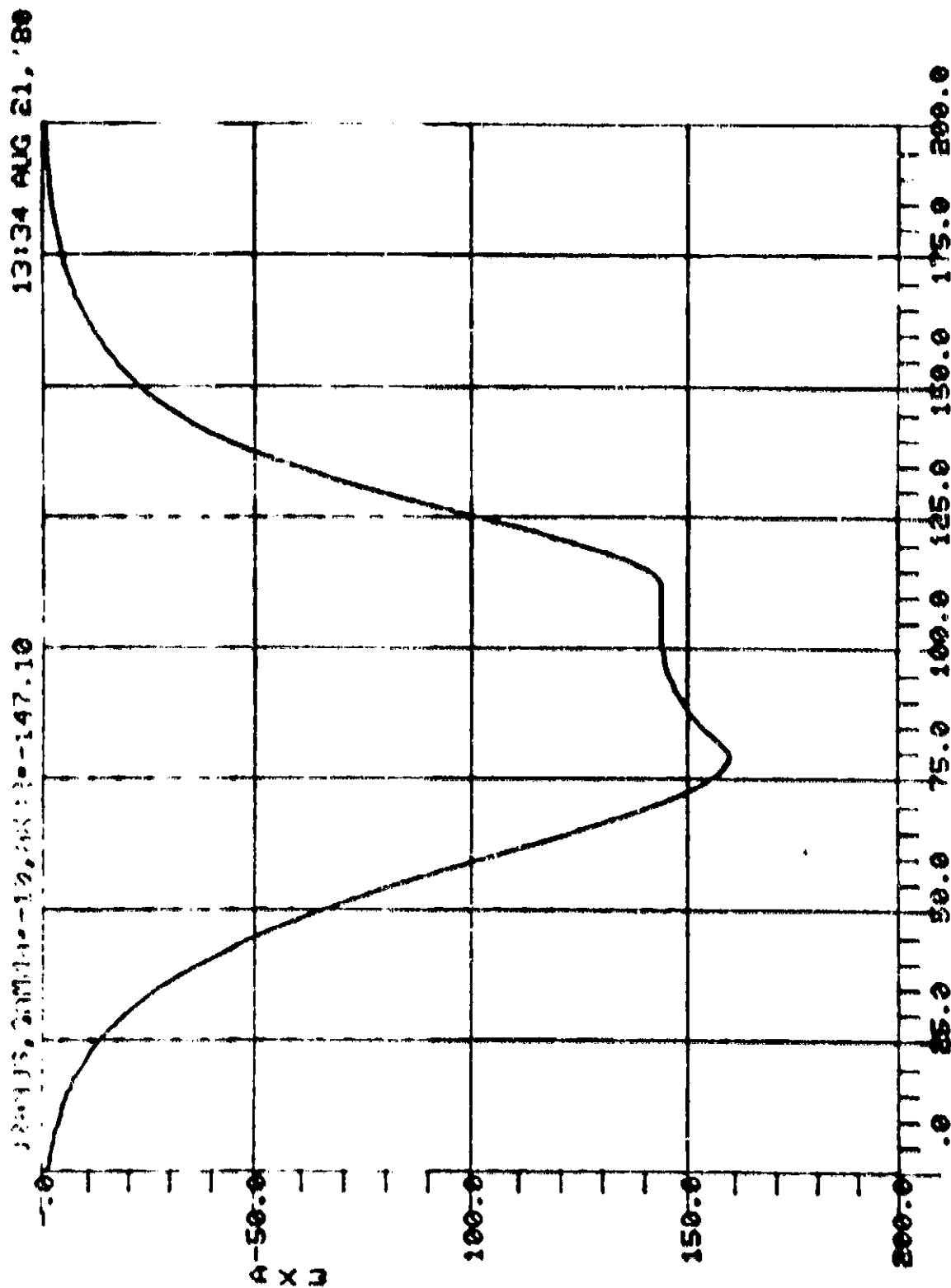


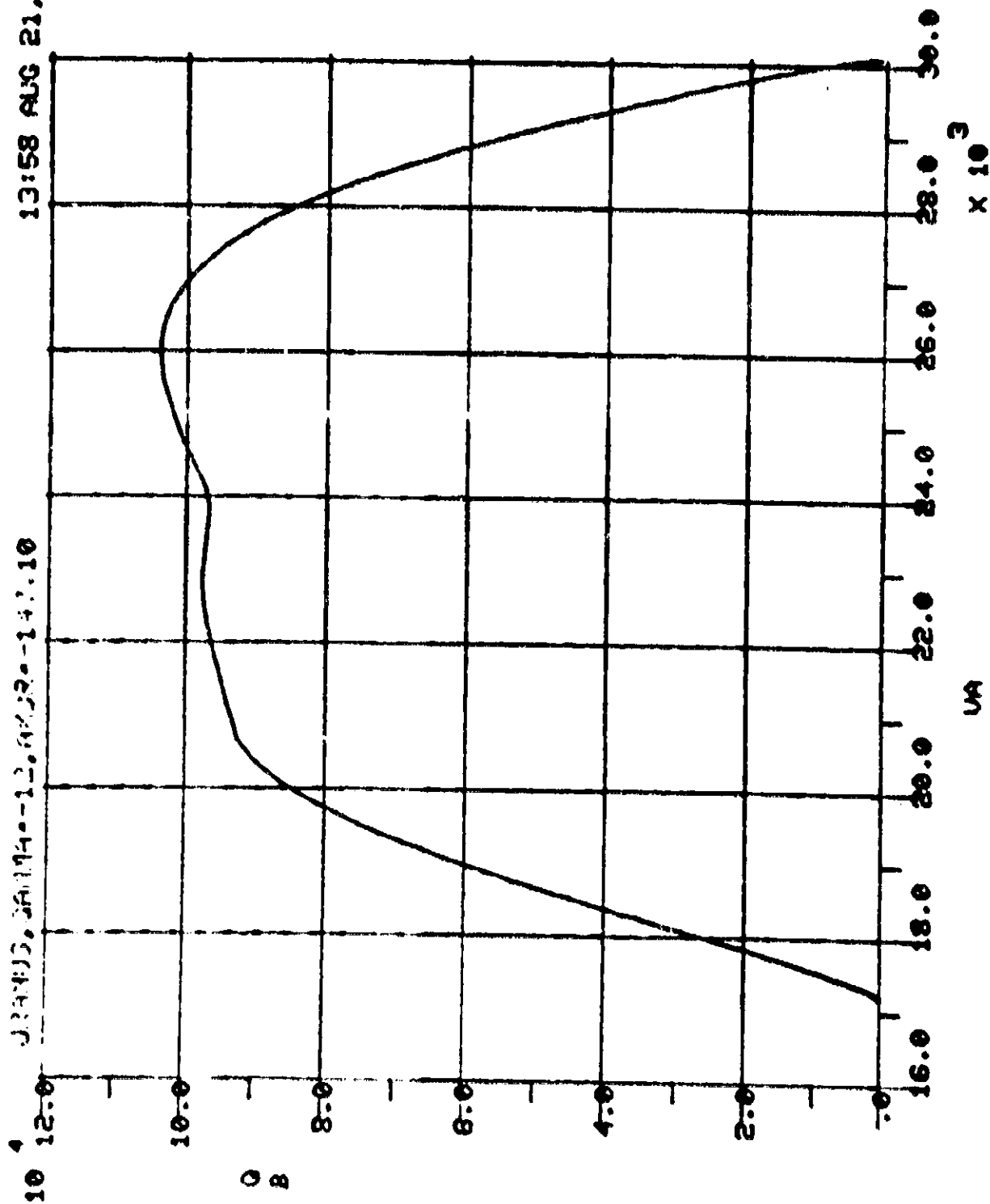
FIGURE C-30



T
FIGURE 3-20

13:58 AUG 21, 88

U.S. AIR FORCE - 12,000 - 14,10



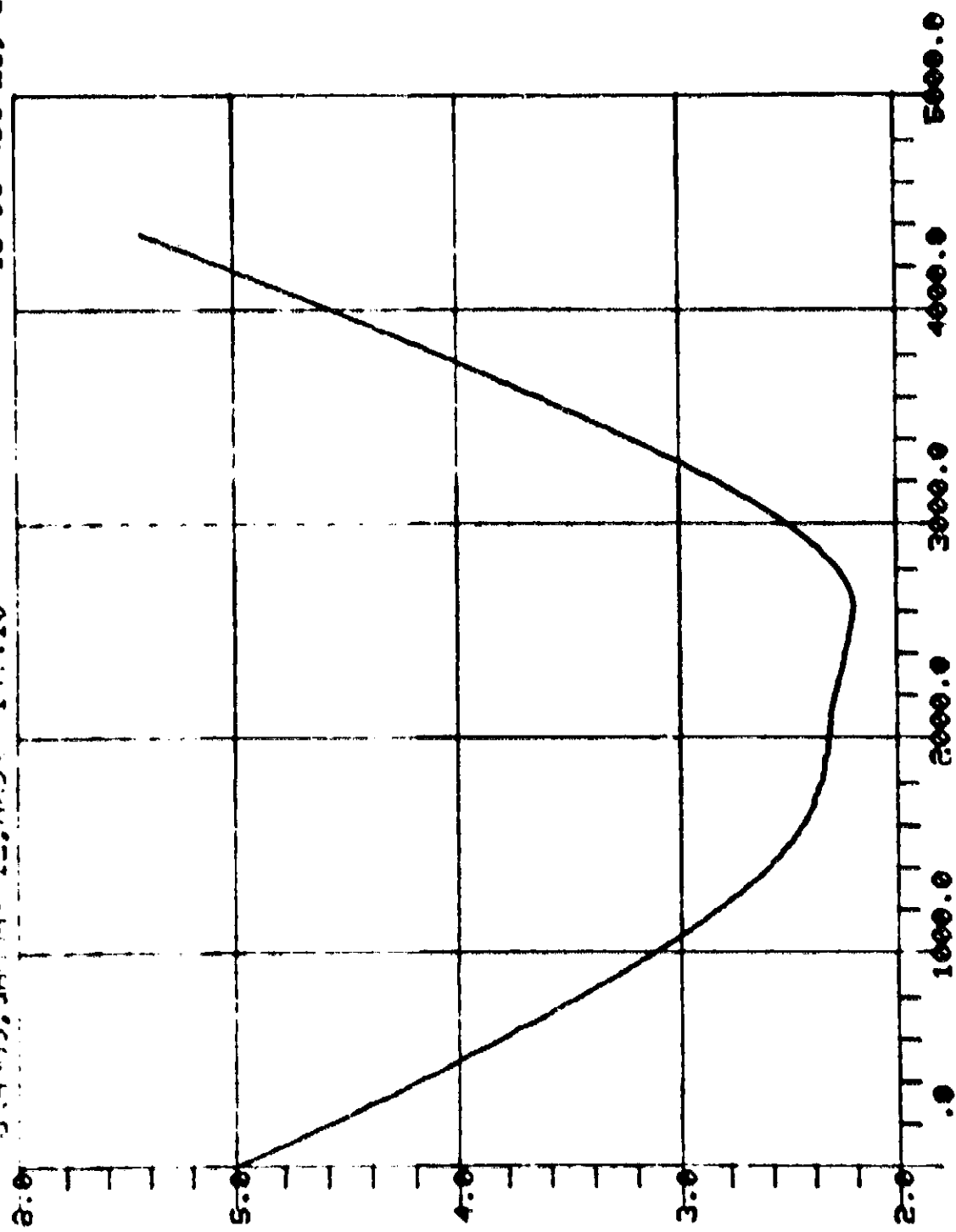
100-368614

13:58 AUG 21, '80

034403, 24114-13, AX30-147.10

10 5 2.0

π



DEND

FIGURE C-42

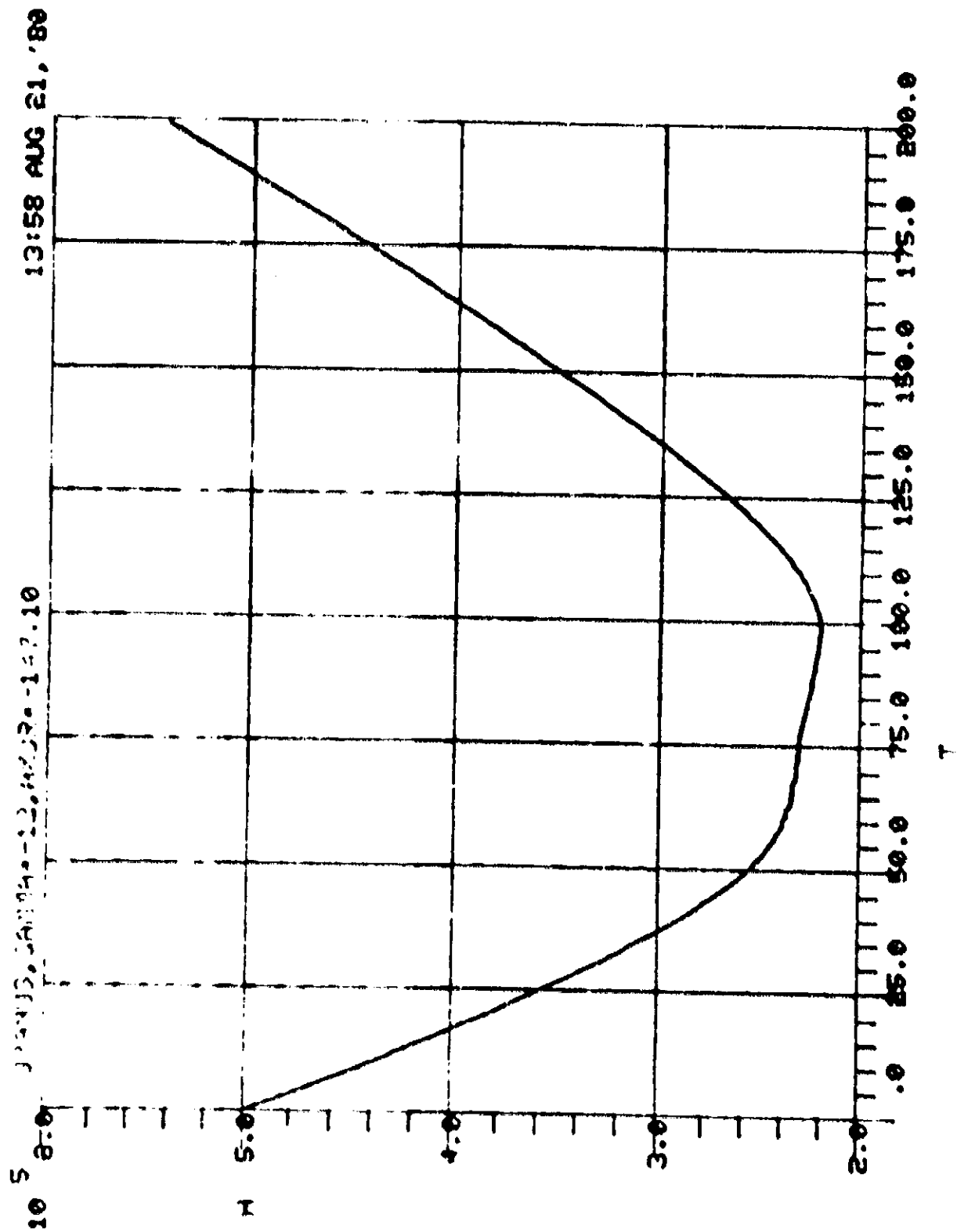
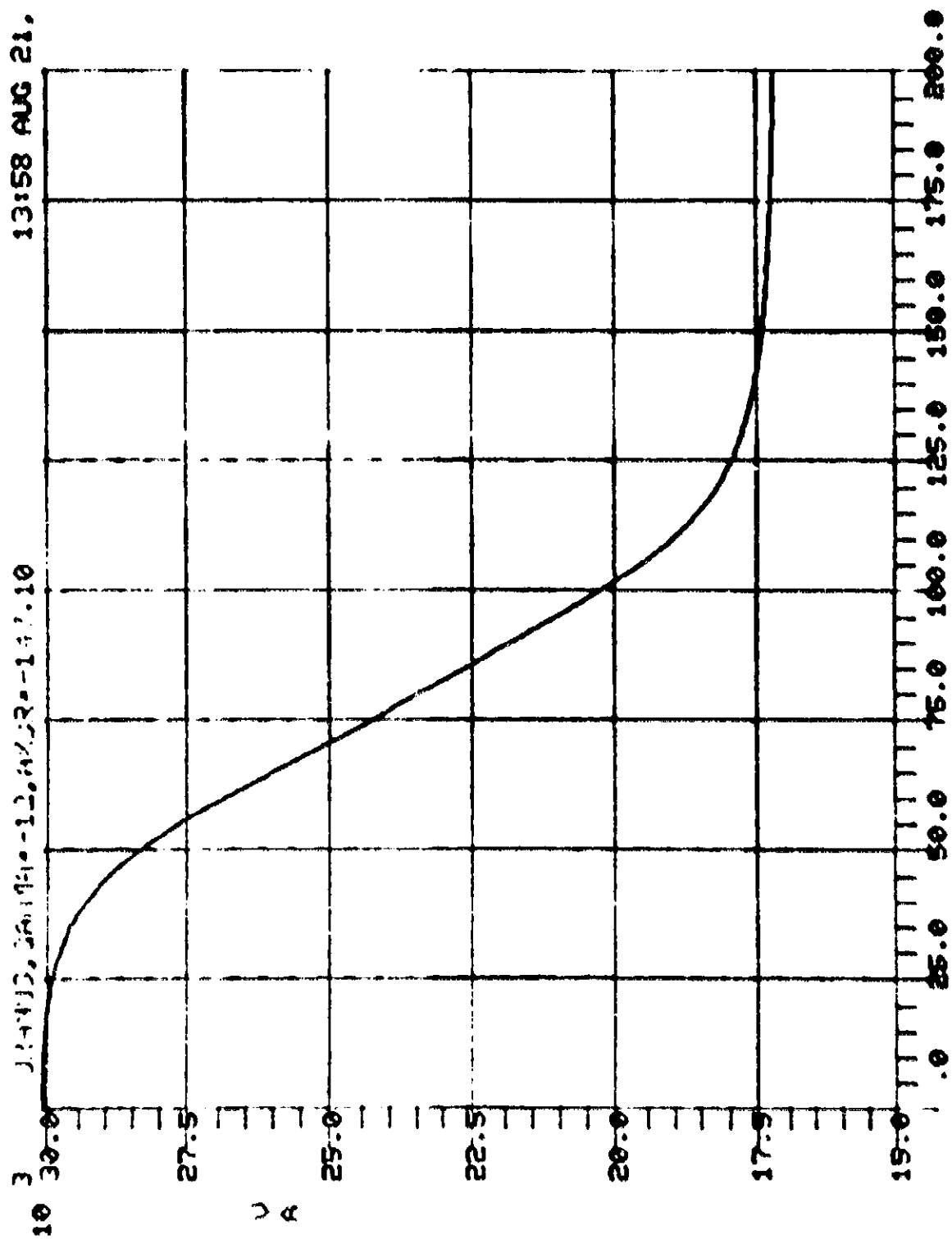


FIGURE C-43

13:58 AUG 21, 80

11-413, 26-1141-12, 413R-141.10

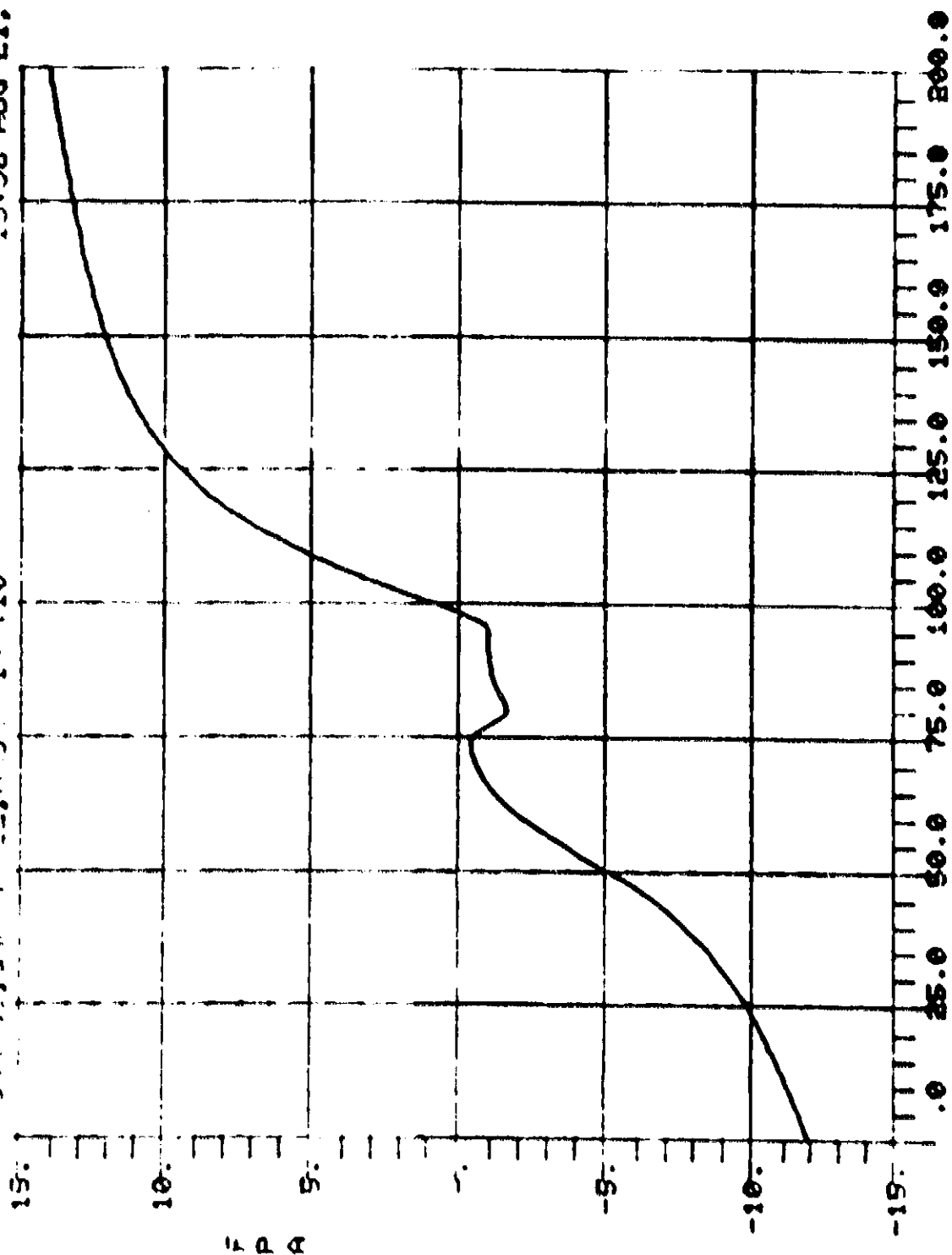


T

FIGURE C-43

13:58 AUG 21, '80

23493.2A 04-12.4 09-1.1.10



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FIGURE C-36

13:58 AUG 21, '80

114910, 201149-12, 000000-147.10

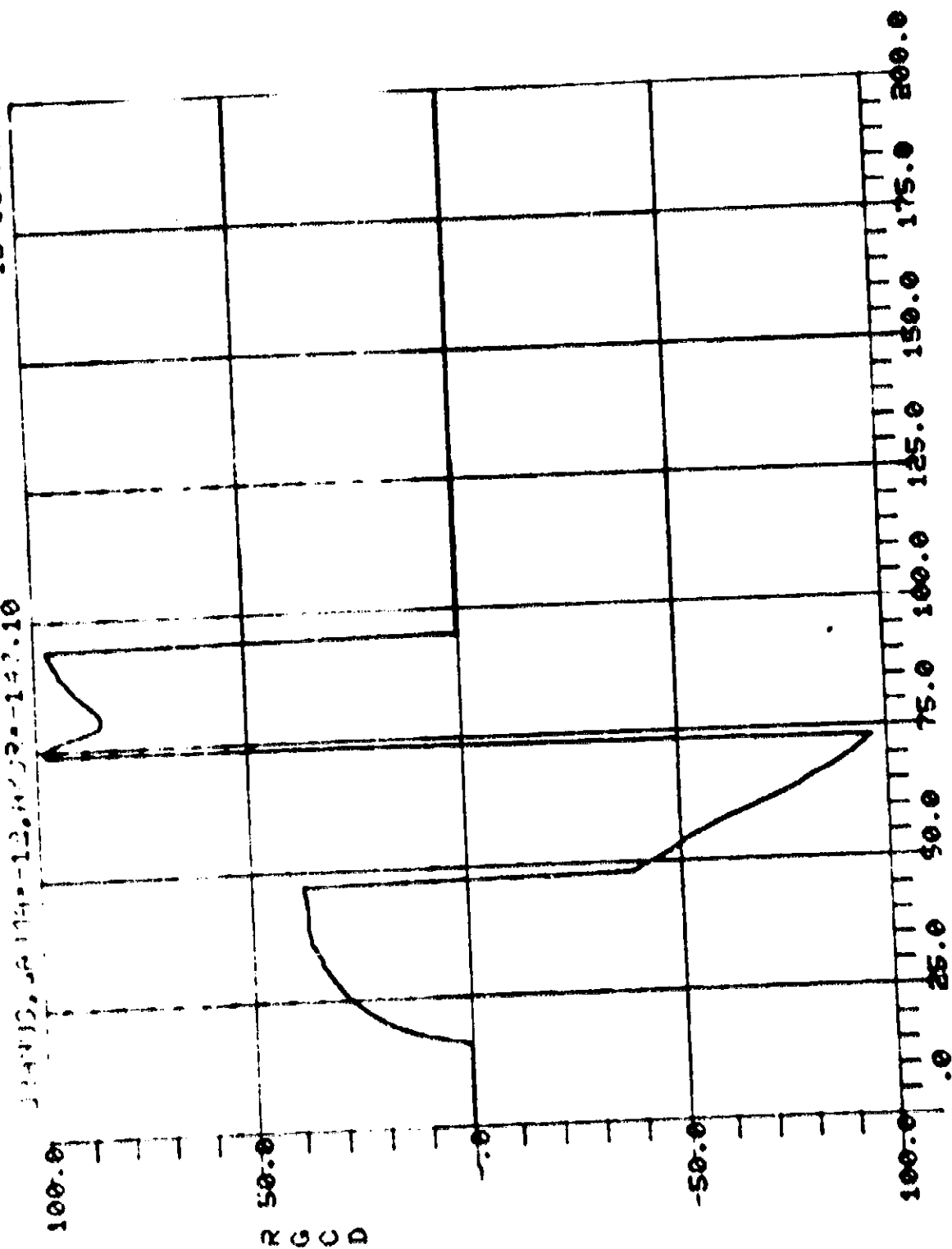


FIGURE C-47

13:58 AUG 21, '80

12403, 2A1174-12.4432-14.10

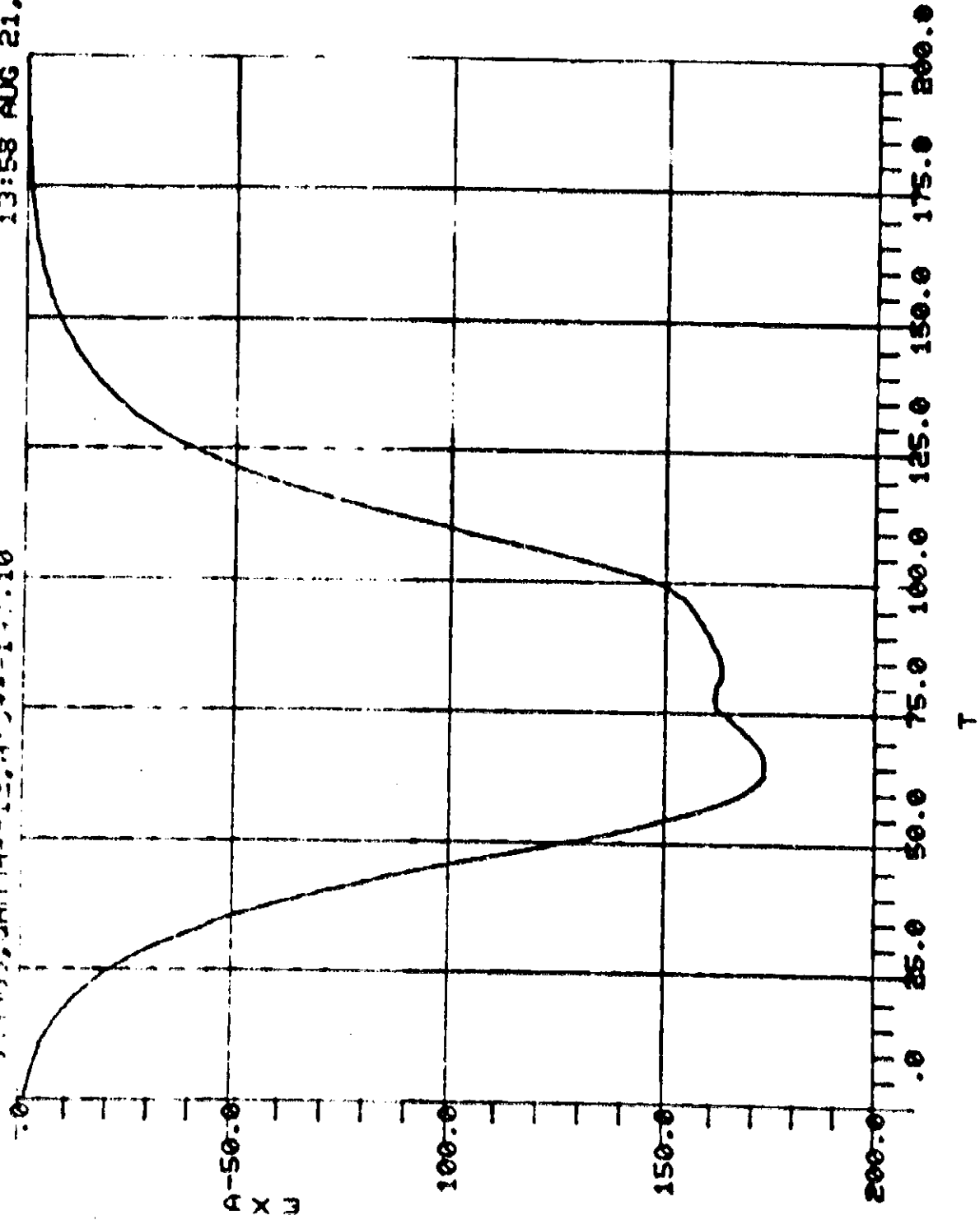


FIGURE C-48